FIRE SENSE: INFRASONIC WILDFIRE DETECTION SENSOR

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PROBLEM STATEMENT & PAST WORK

DETECTING FIRES USING INFRASOUND

- Early detection to expedite response times
- Sensors to identify low frequency signatures
  - ⑩ Infrasound: <20Hz

- Past teams prioritized proof of concept work:
  - PVC enclosure with a parachute delivery method
  - Signal filter & mesh network development

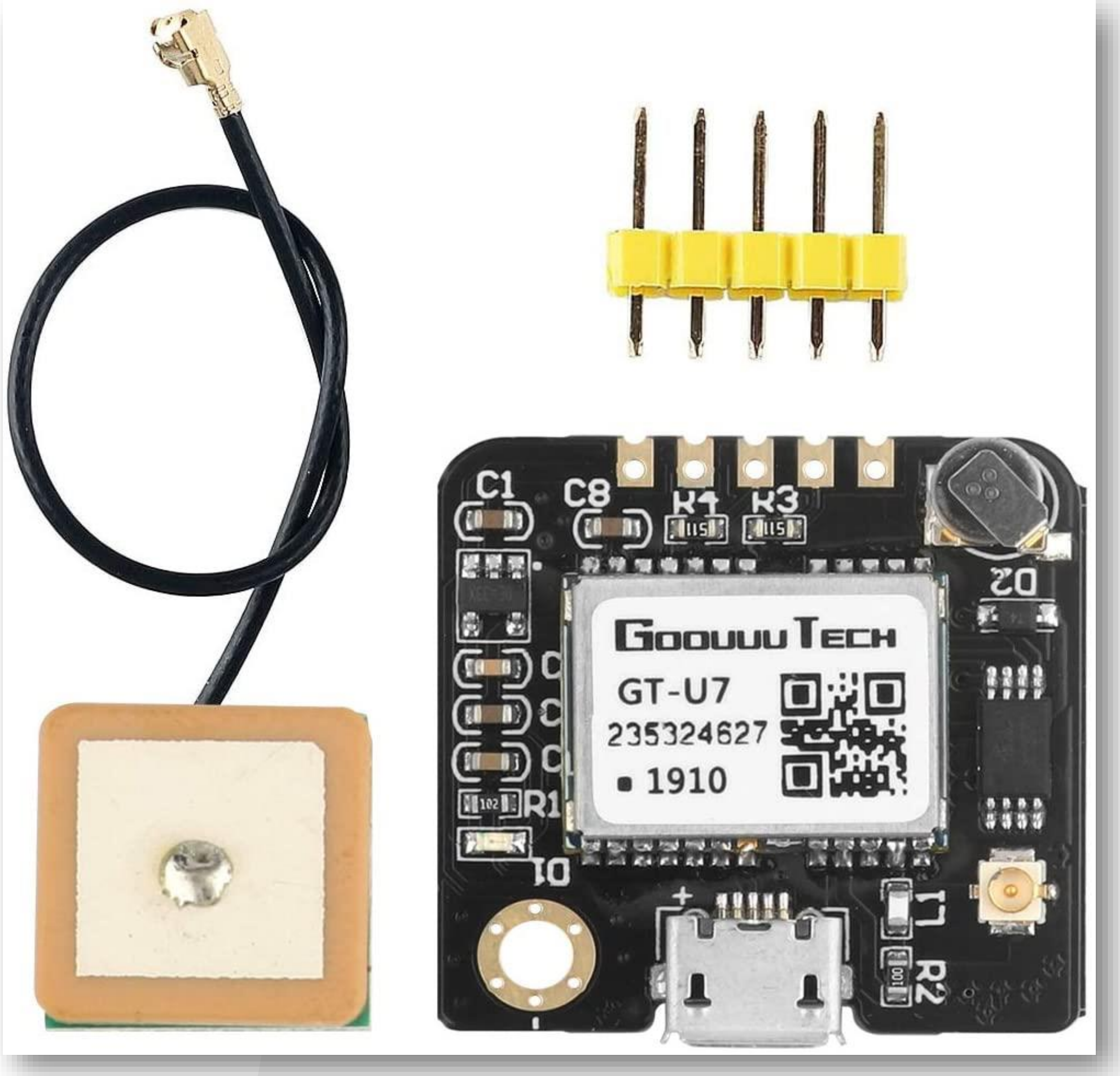
PLAN & OBJECTIVES MOVING FORWARD

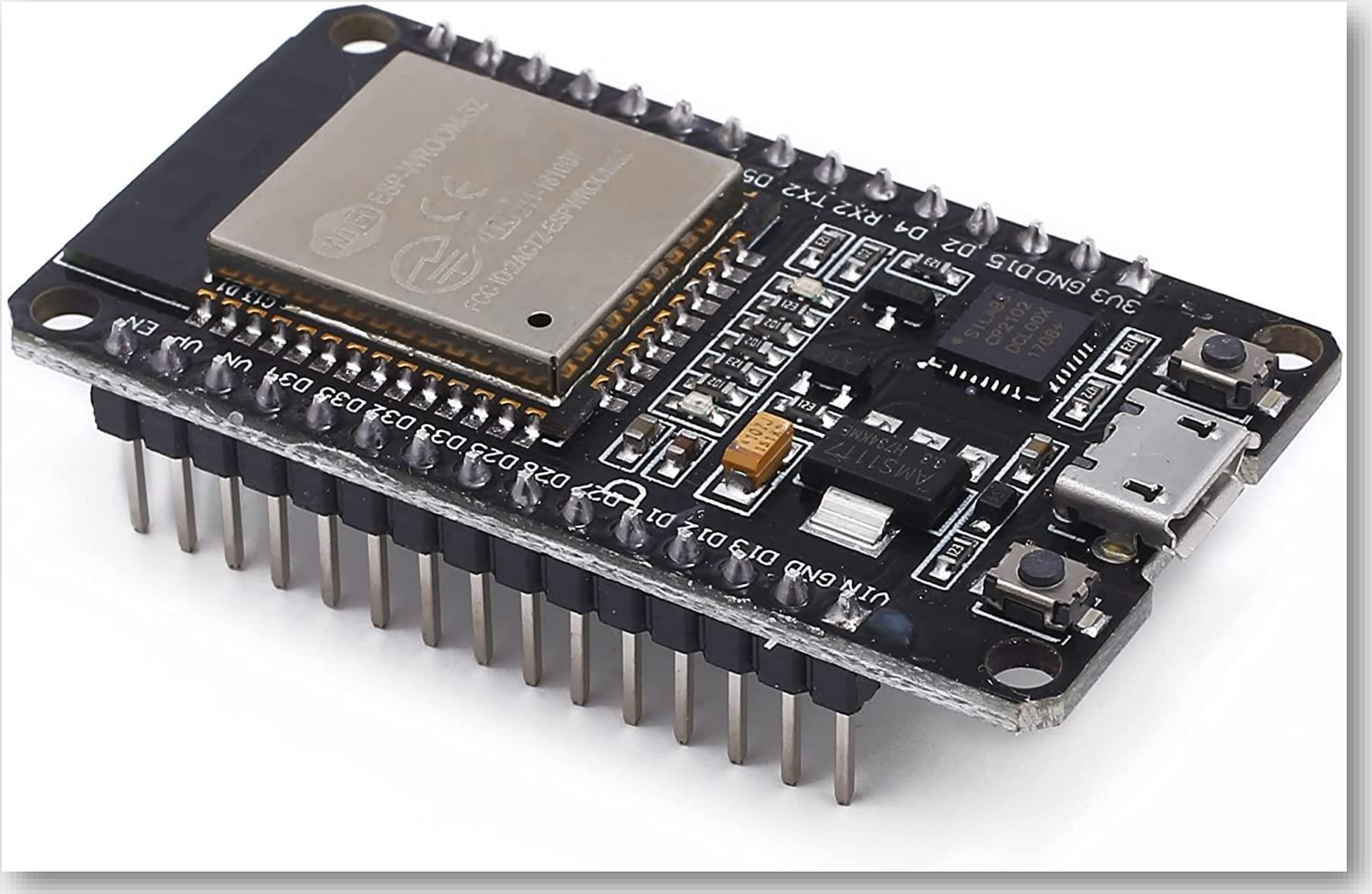
- Troubleshoot PCB
- Condense Circuitry
- Battery/Life
- Networking Communications
- Signal Identification /Analysis
- Payload Design /Delivery

PCB DESIGN

REQUIRED COMPONENTS

- GPS – Node Location
- Microphone – Audio Input
- Signal Filtering – Chebyshev Type I

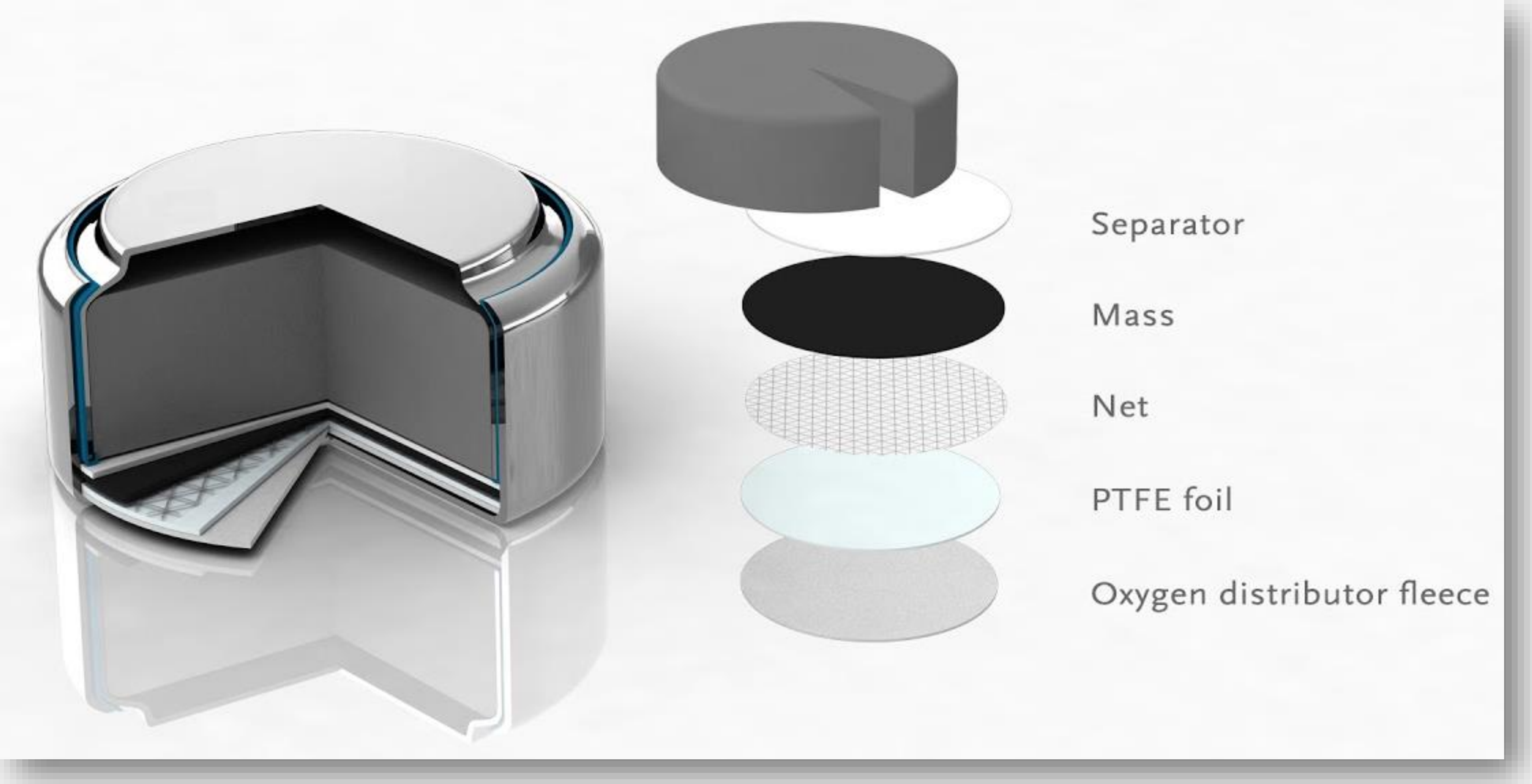


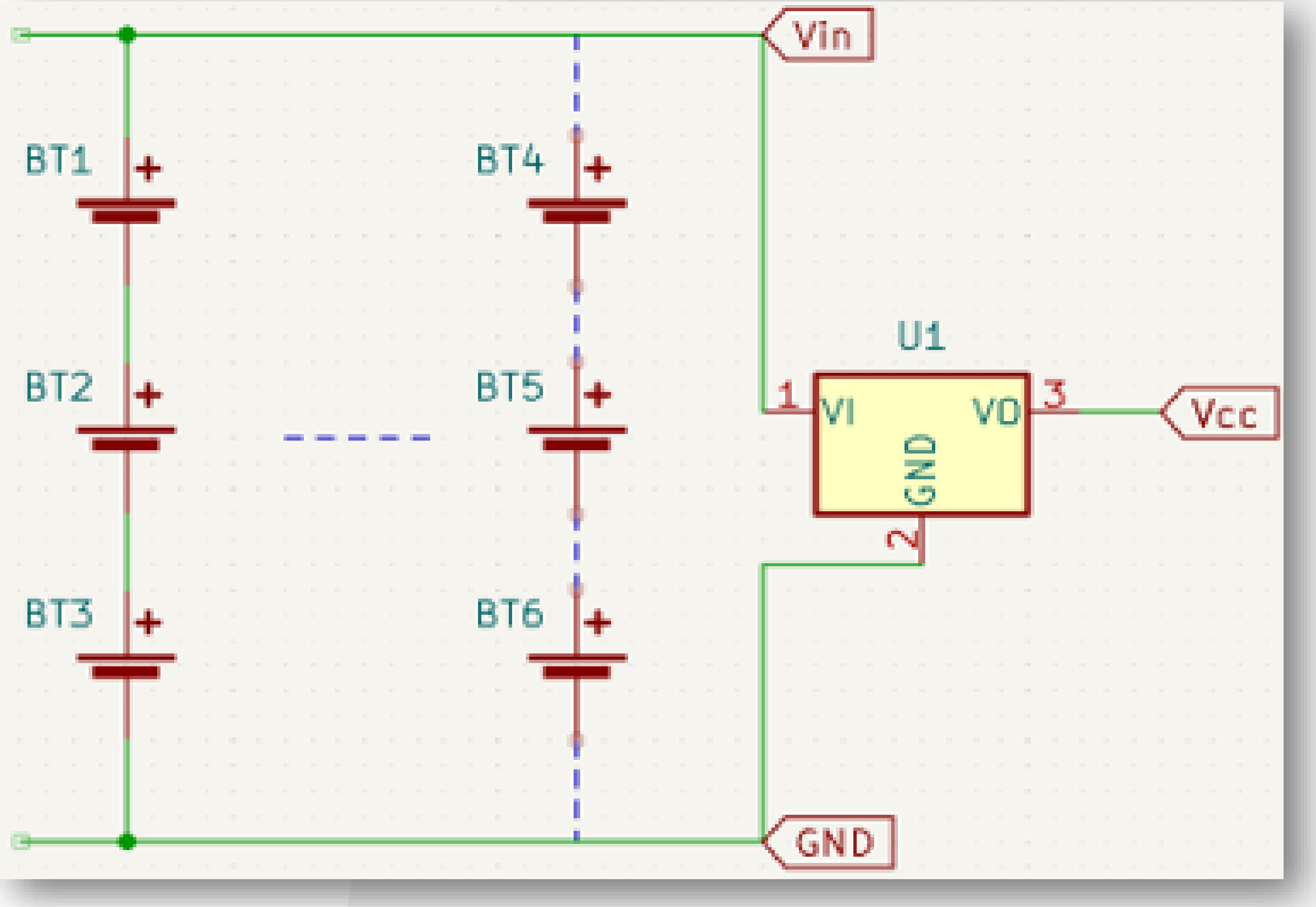


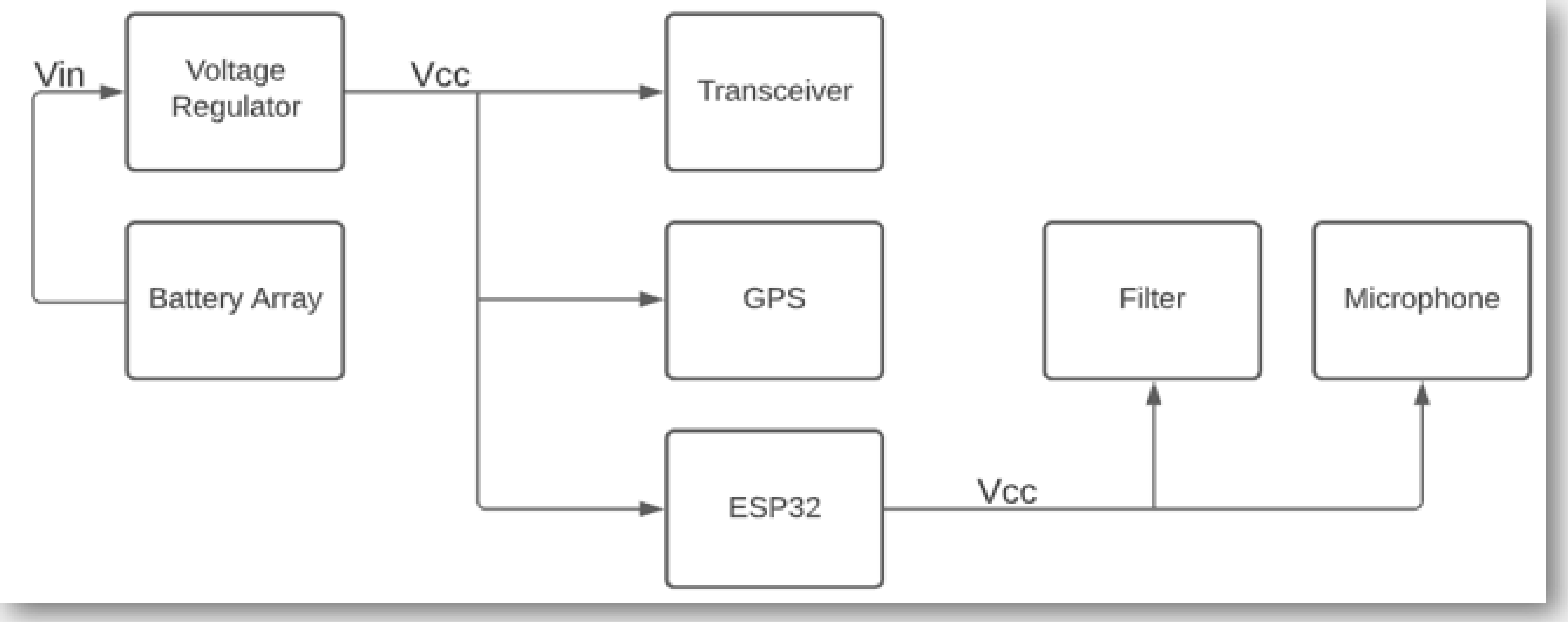
- Microcontroller – Processing
- Radio – Message Transmission
- Batteries – System Power

BATTERY/POWER MANAGEMENT

- Zinc Air:
  - Size: 11.6mm x 5.4mm
  - Voltage: 1.45V (Nominal)
  - Capacity: 600 mAh

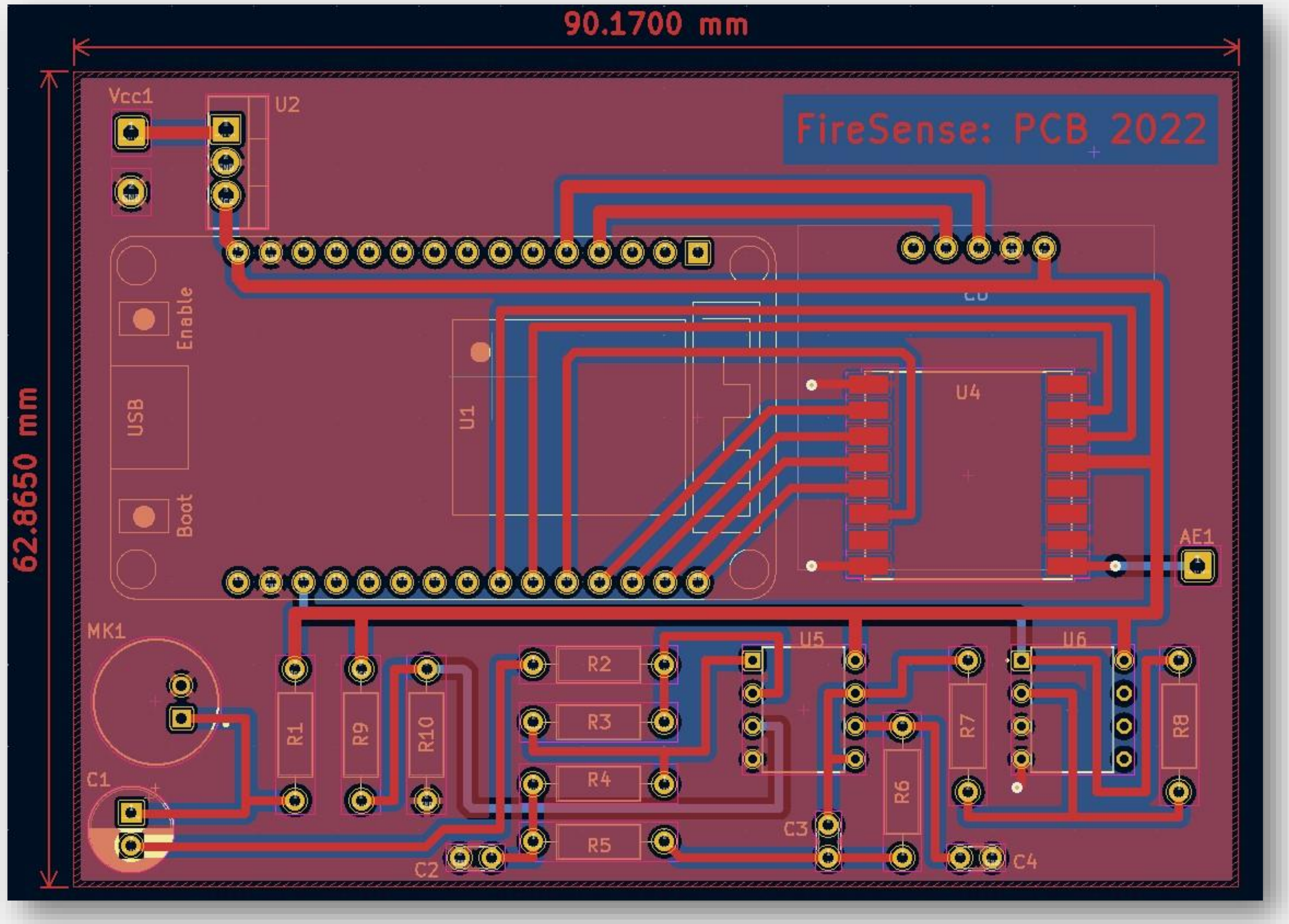


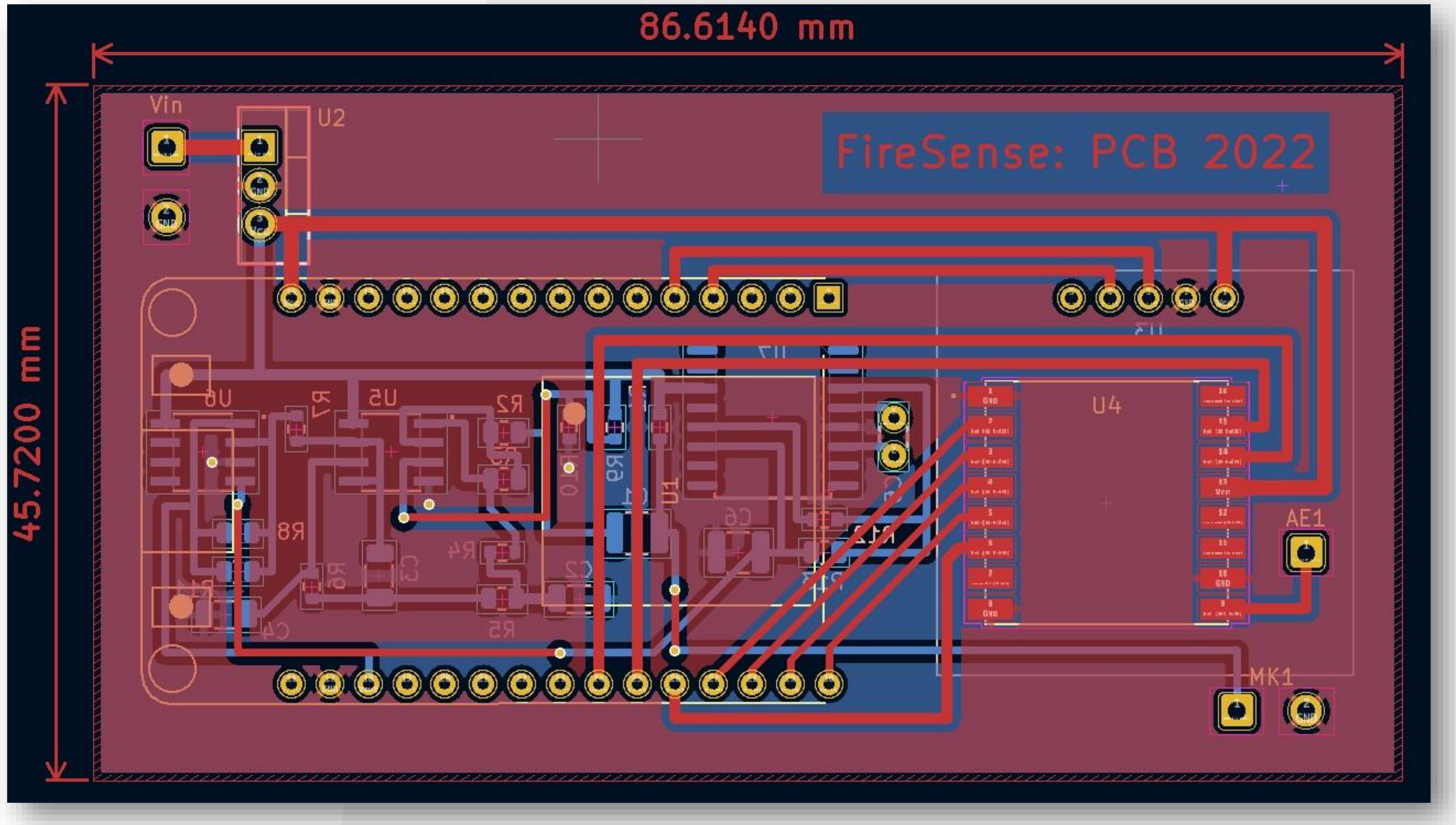




PCB MANUFACTURING

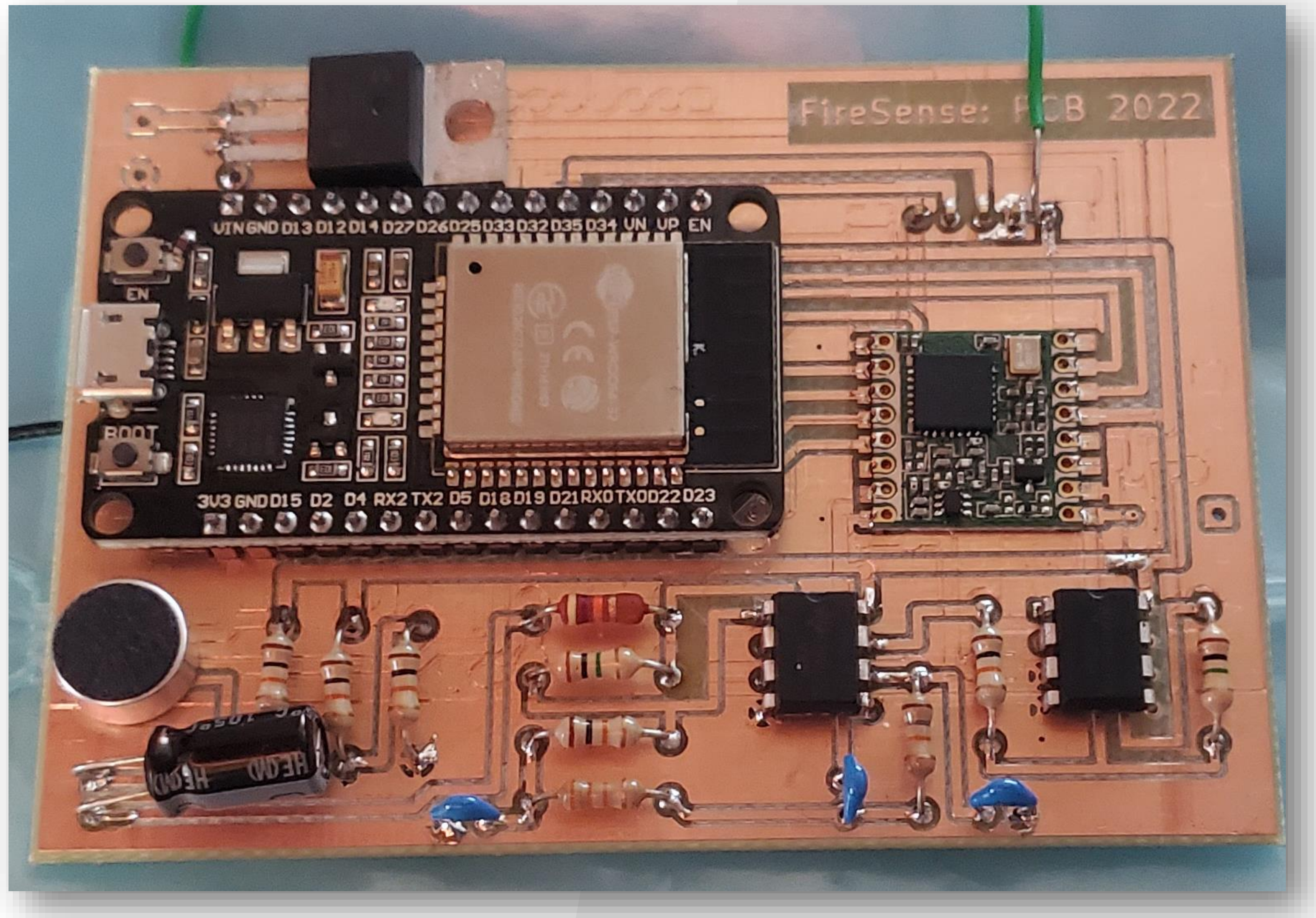
- PCB v1: THT Design
  - Version 1 of the PCB using through hole filter components
  - Non-plated through holes

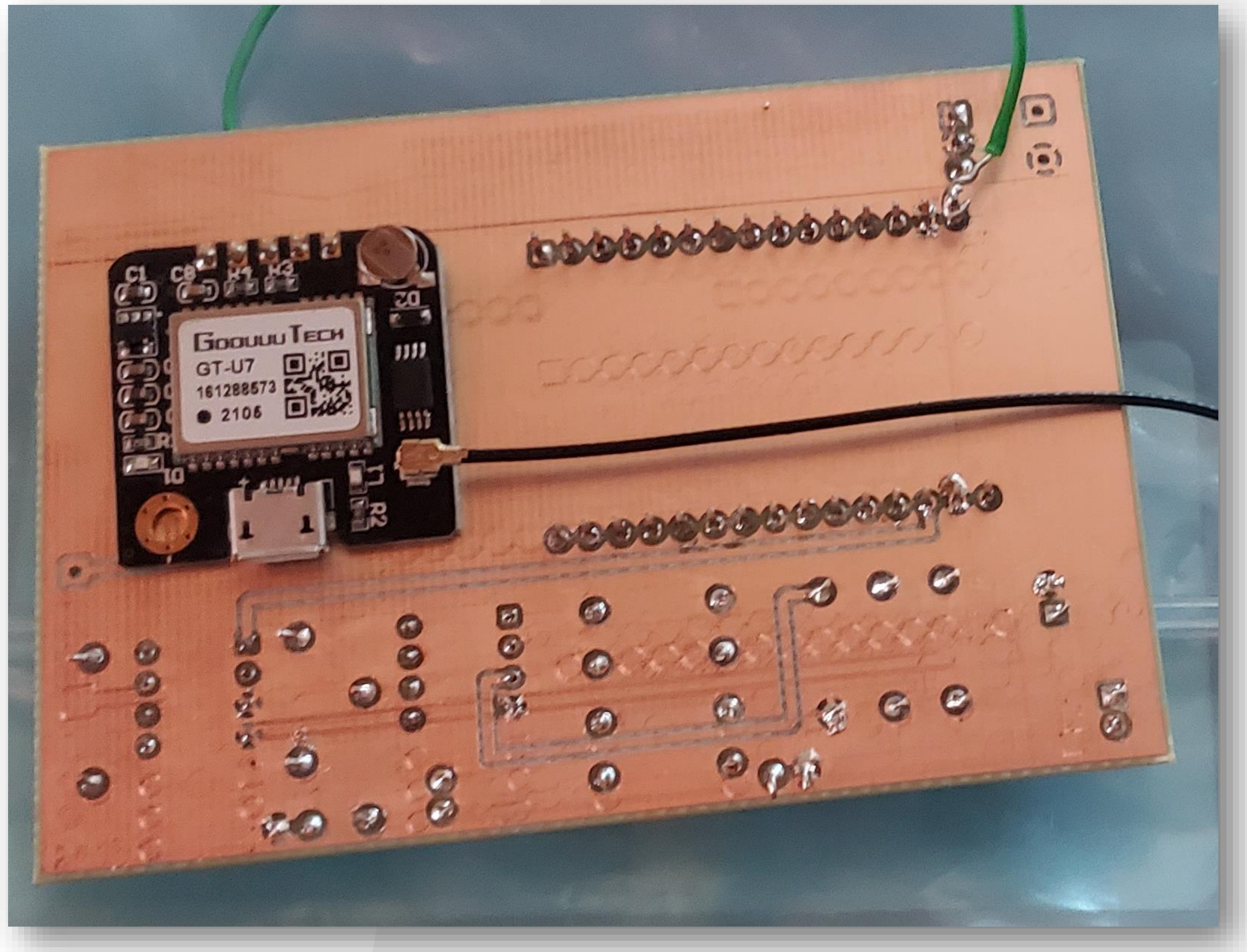




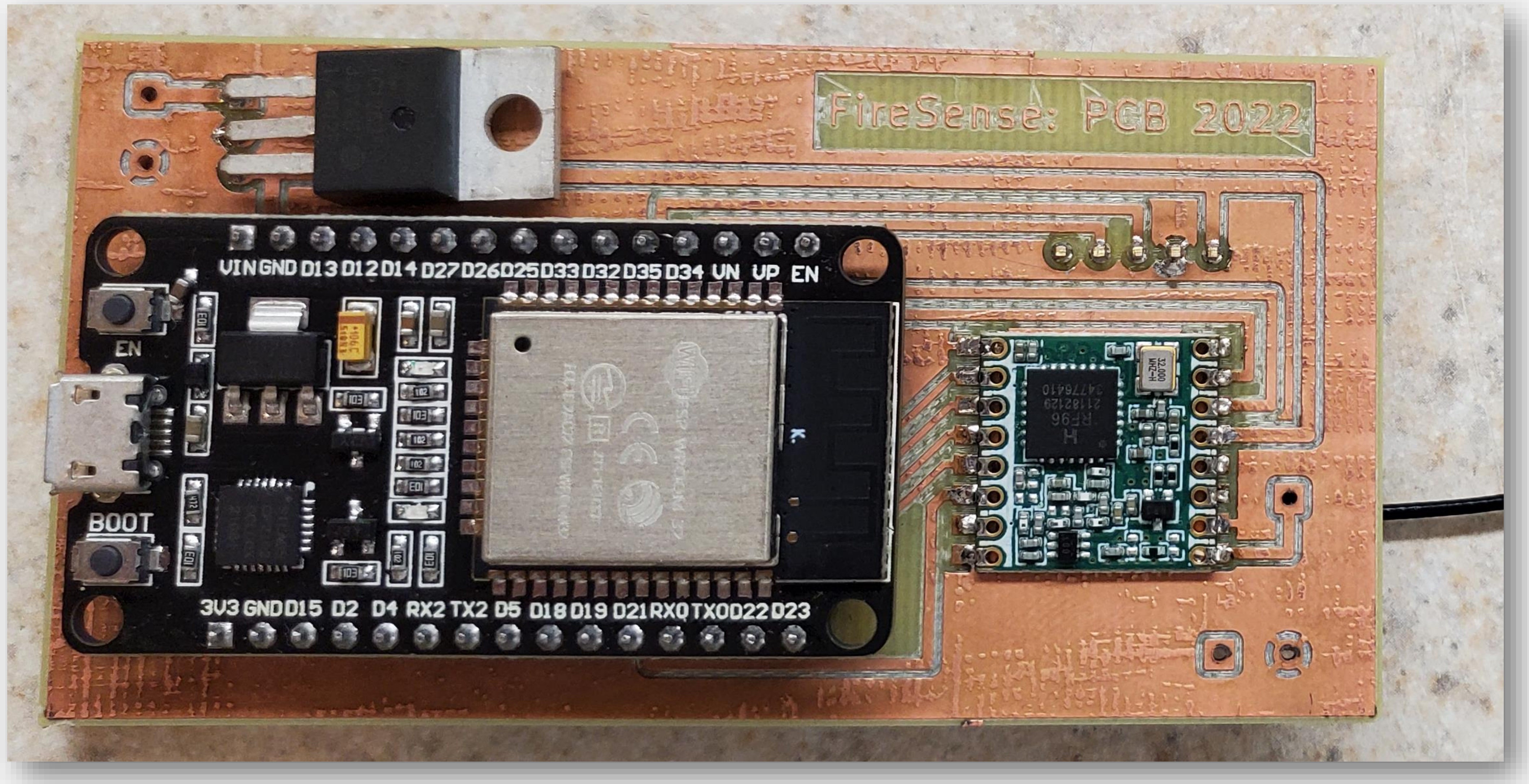
- PCB v2: SMT Design
  - Version 2 of the PCB optimized using surface mount filter components
  - <u>**30%**</u> size reduction from PCB v1

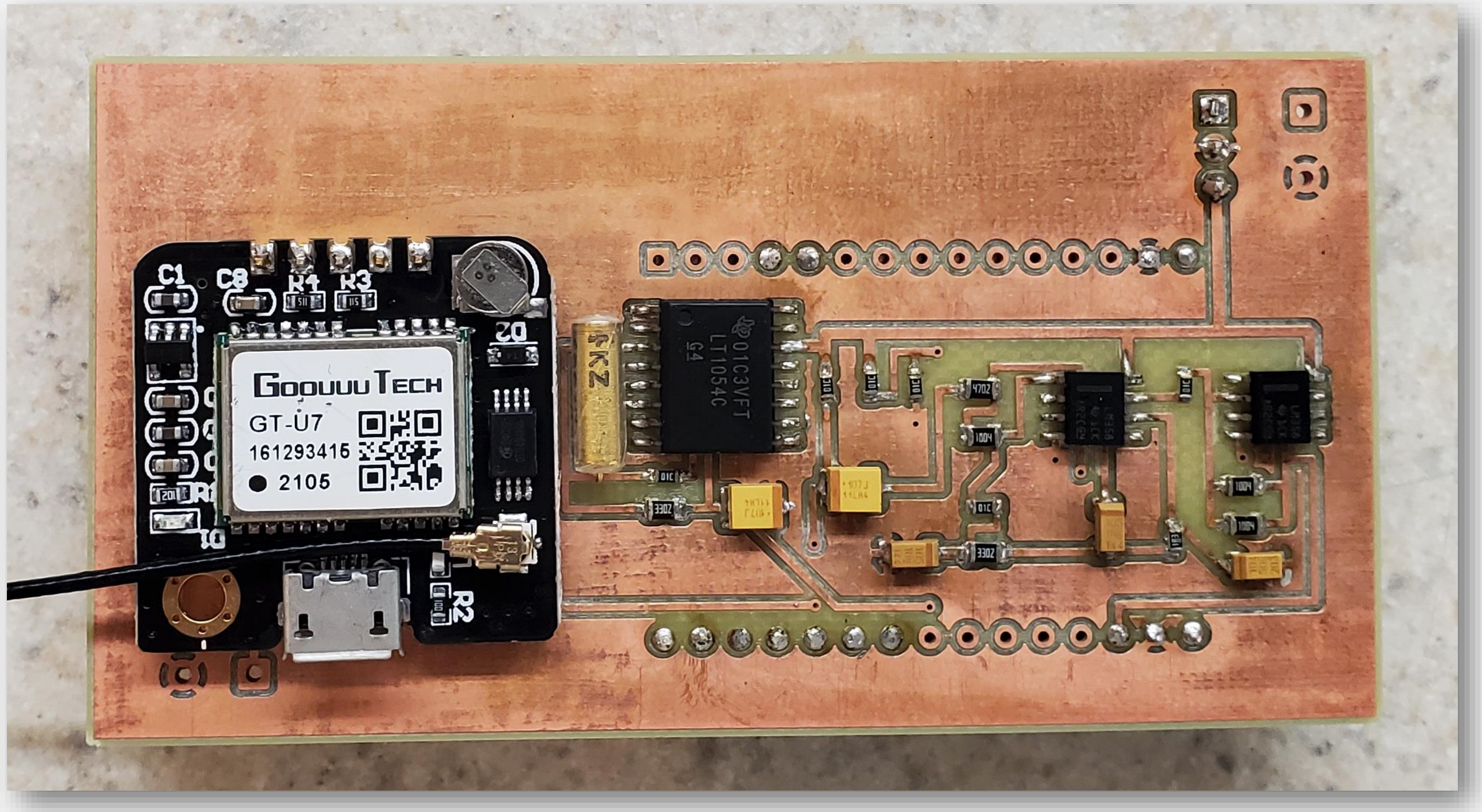
PCB v1:


FireSense: PCB 2022


GoouuuTech
GT-U7

PCB v2:

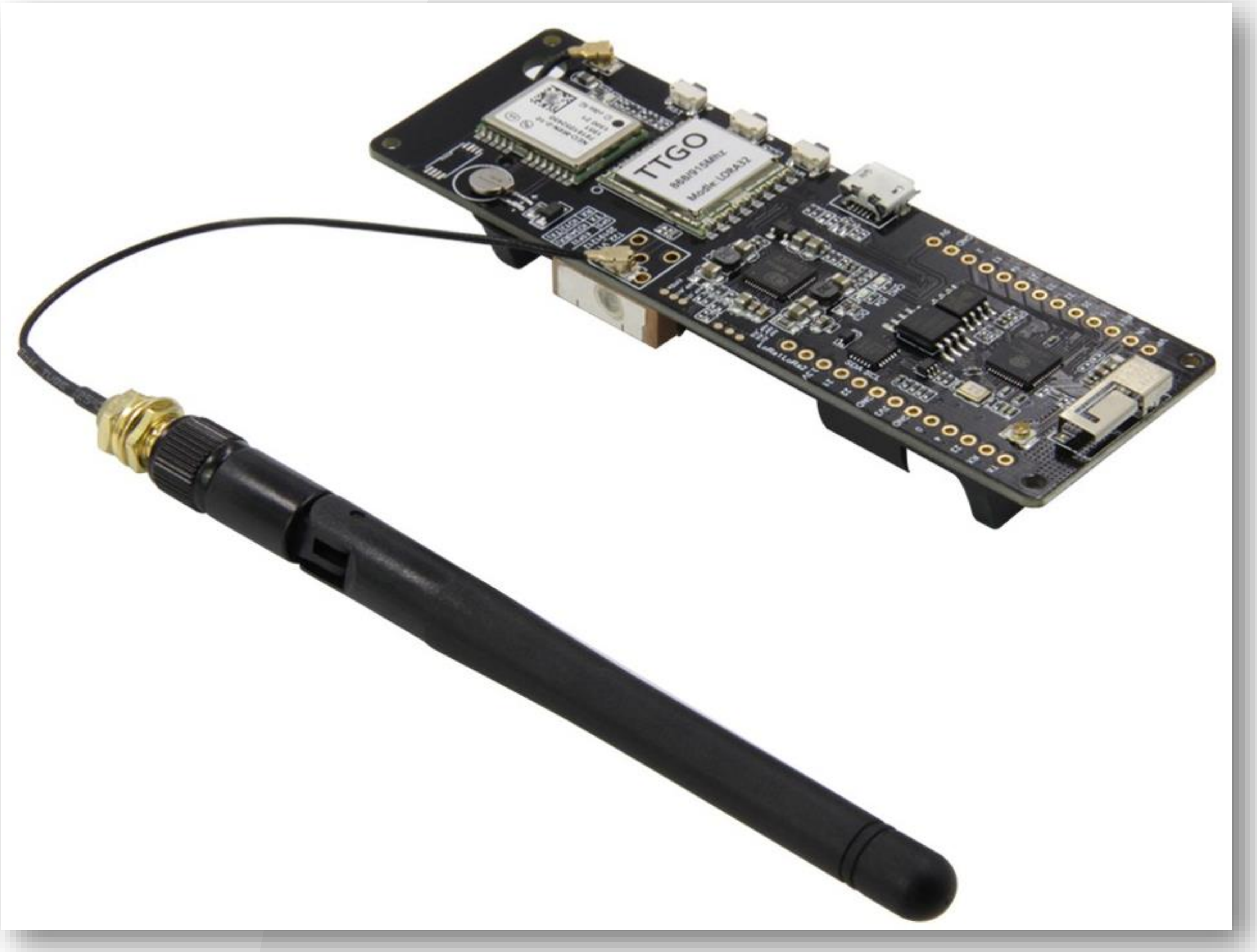

FireSense: PCB 2022
BOOT
EN

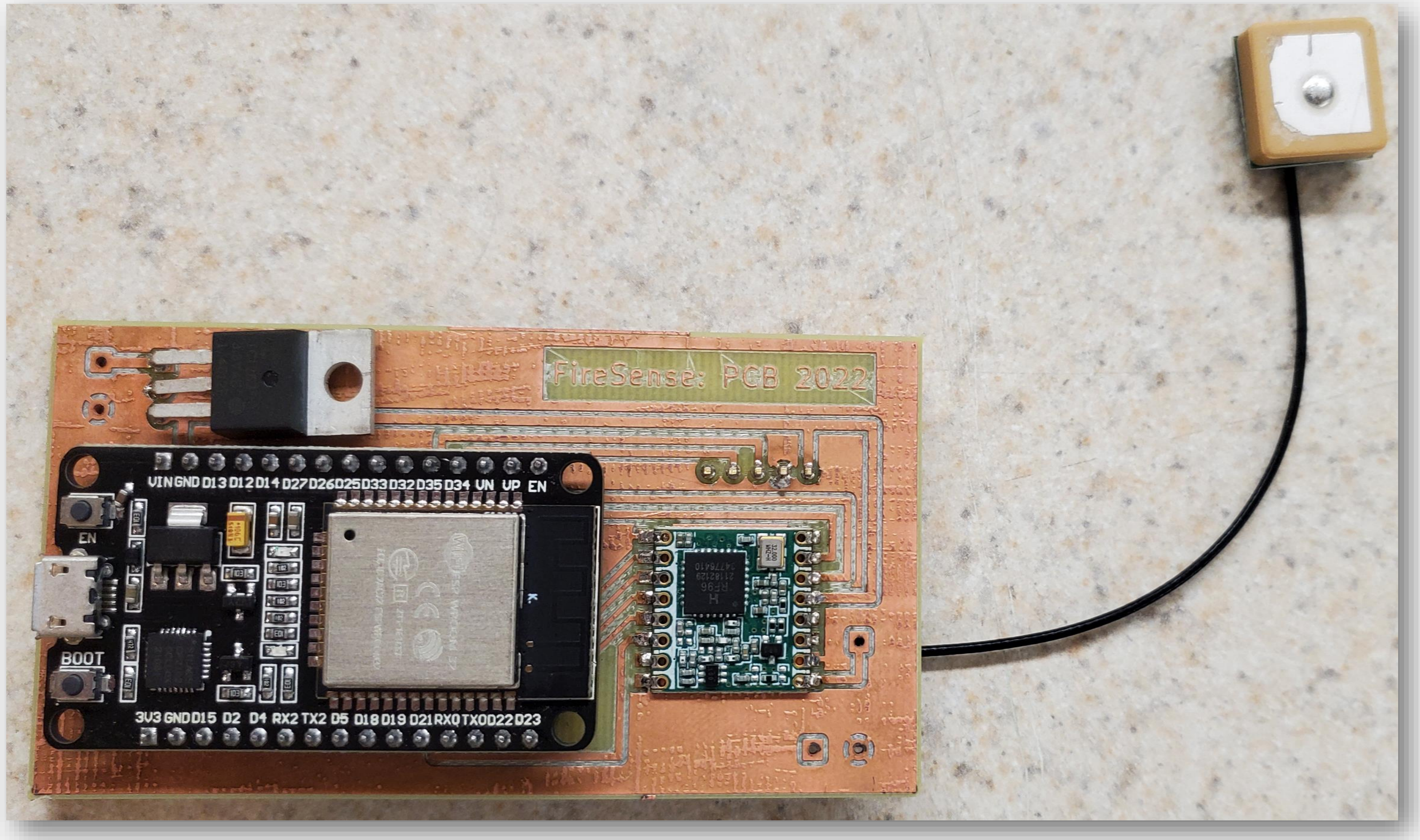

GoouuuTech
GT-U7
161293415
2105

ELECTRONICS PER-UNIT COST

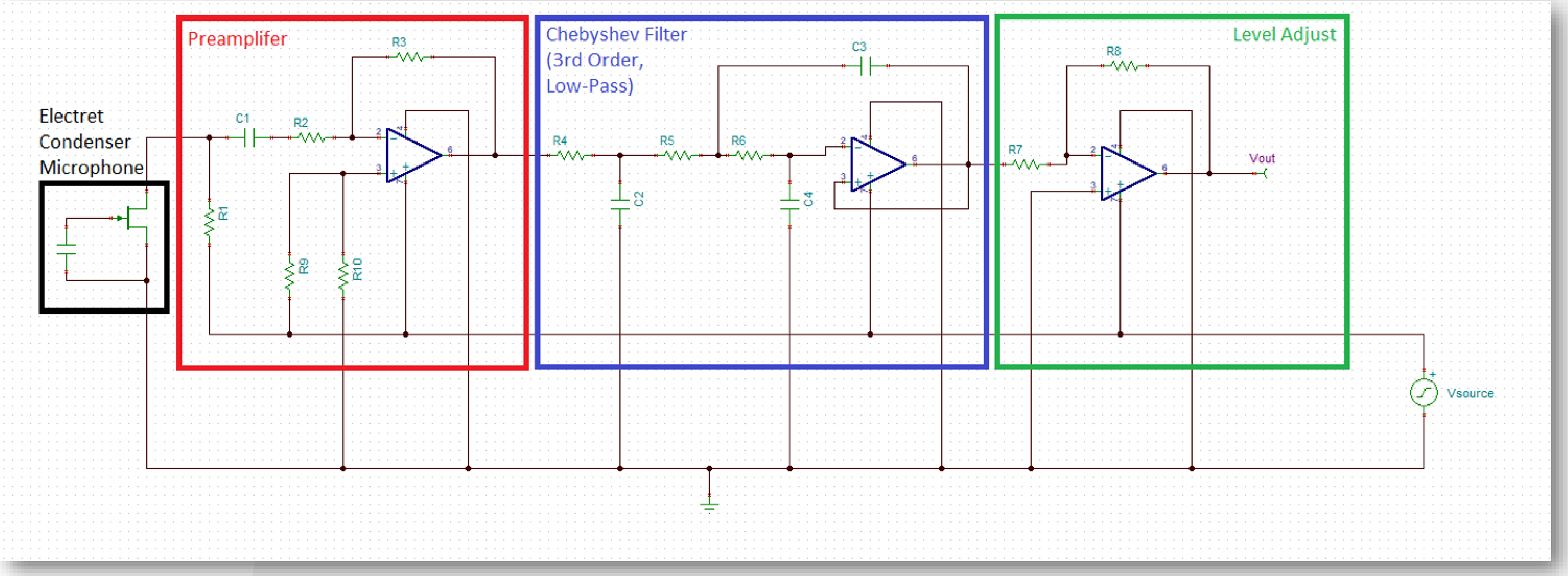
- Previous team's components averaged $50 per unit.
  - High functionality development board

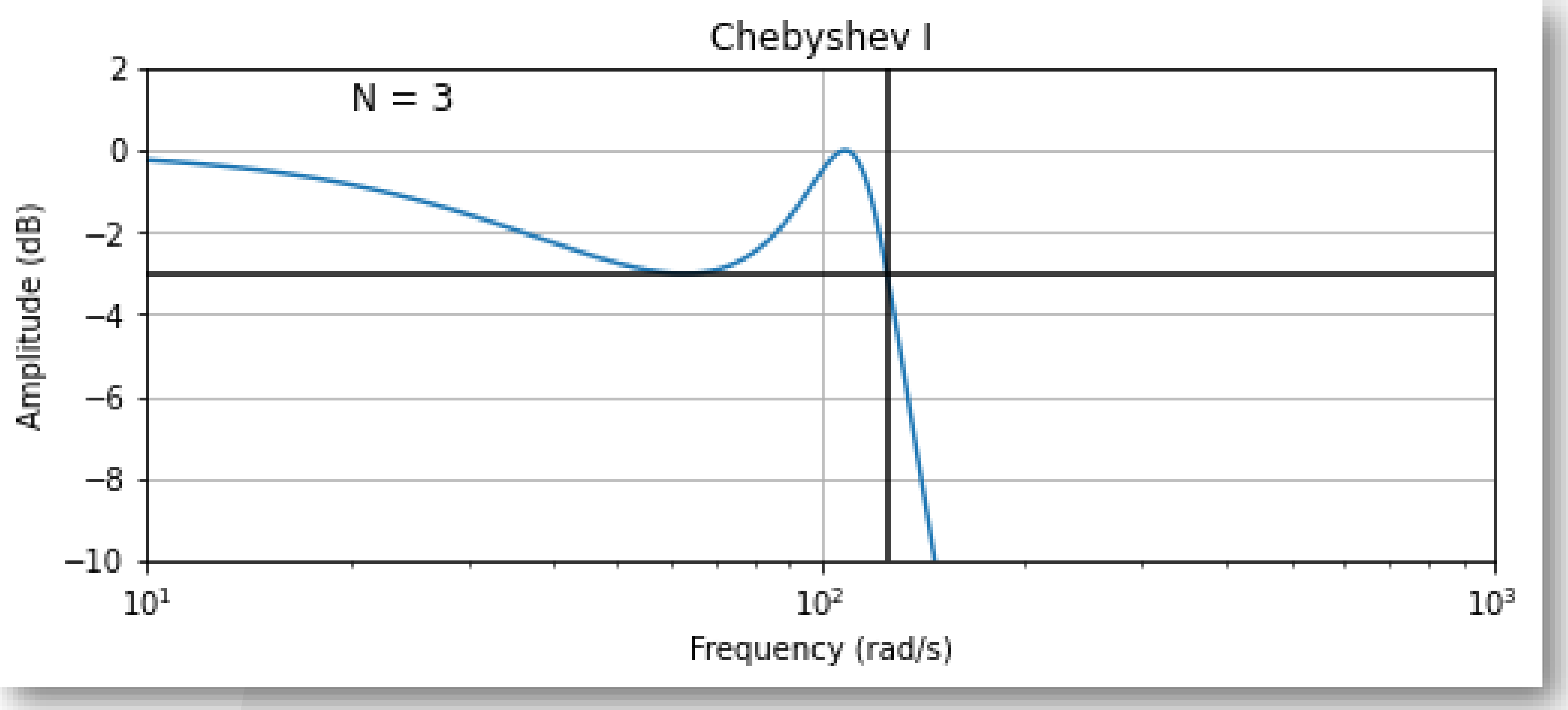
- Current component selection has reduced this cost to an average of $32 per unit.
  - Reducing per-unit cost by <u>**36%**</u>





SIGNAL FILTERING

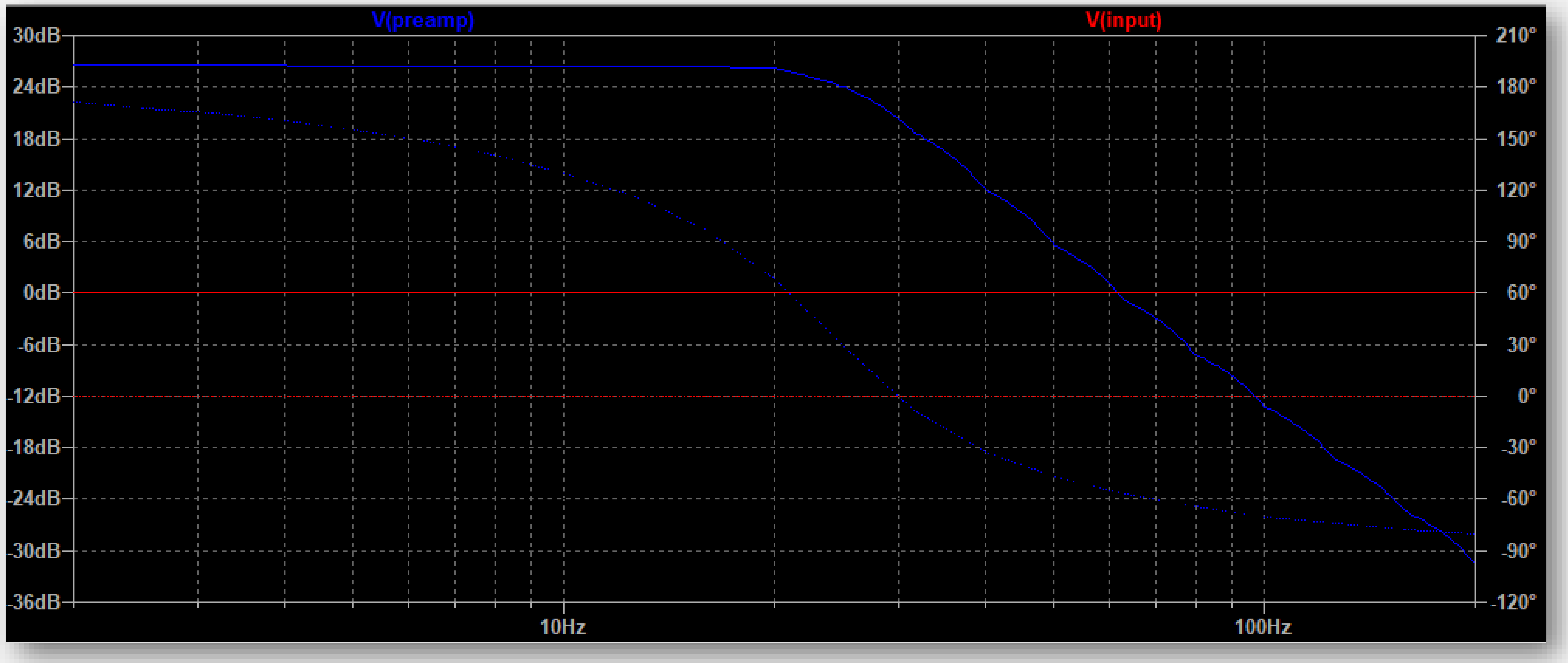


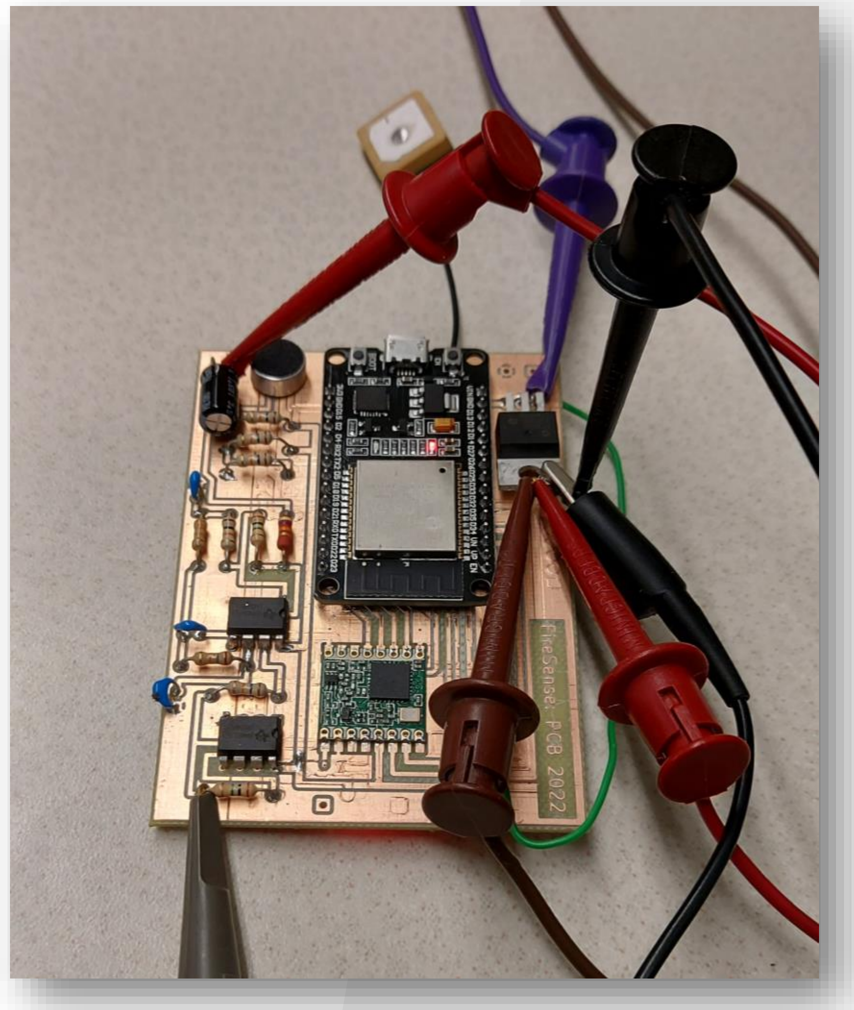


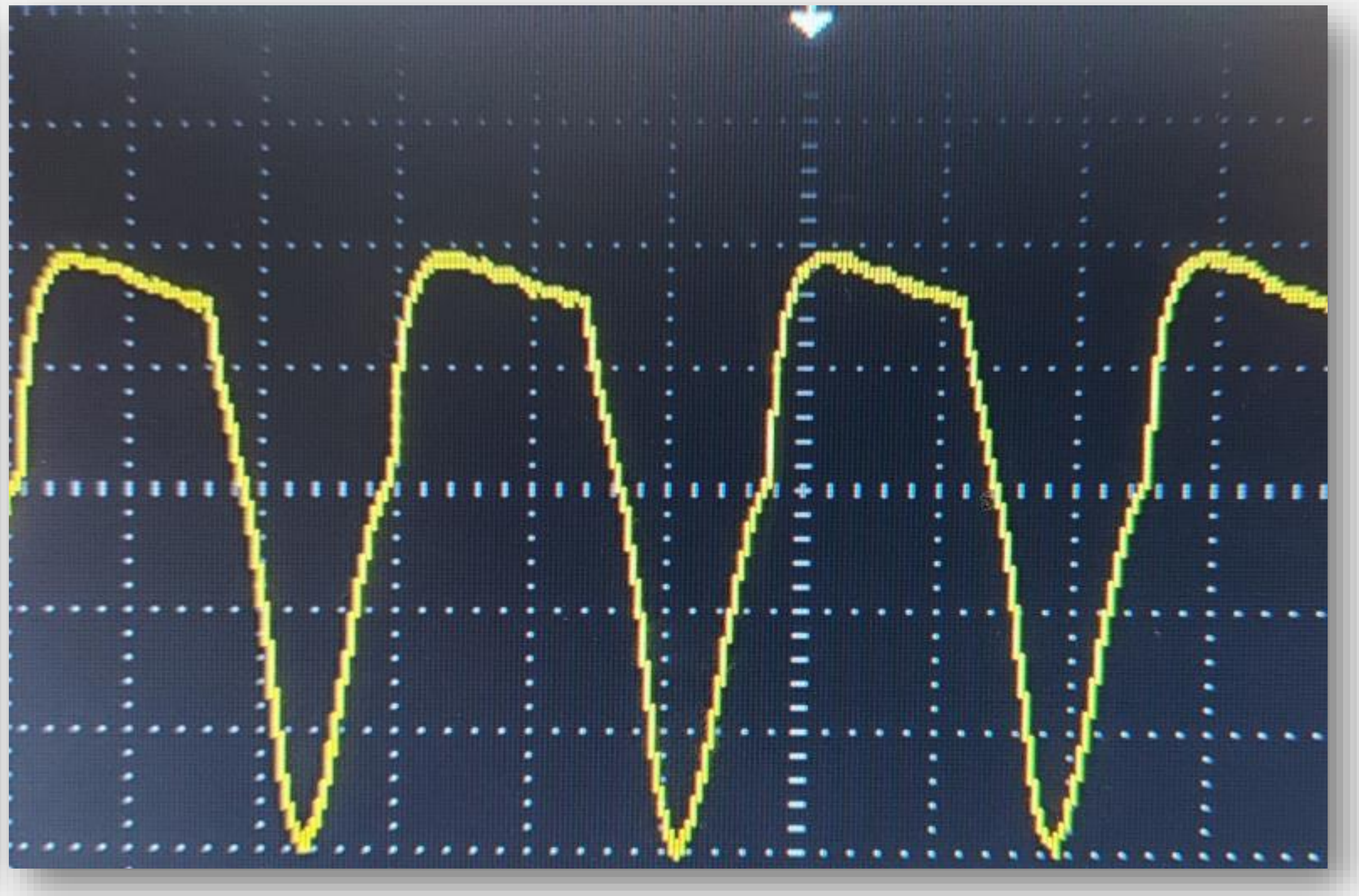
- Sallen-Key Topology
- Low-pass configuration
- Properly scalable

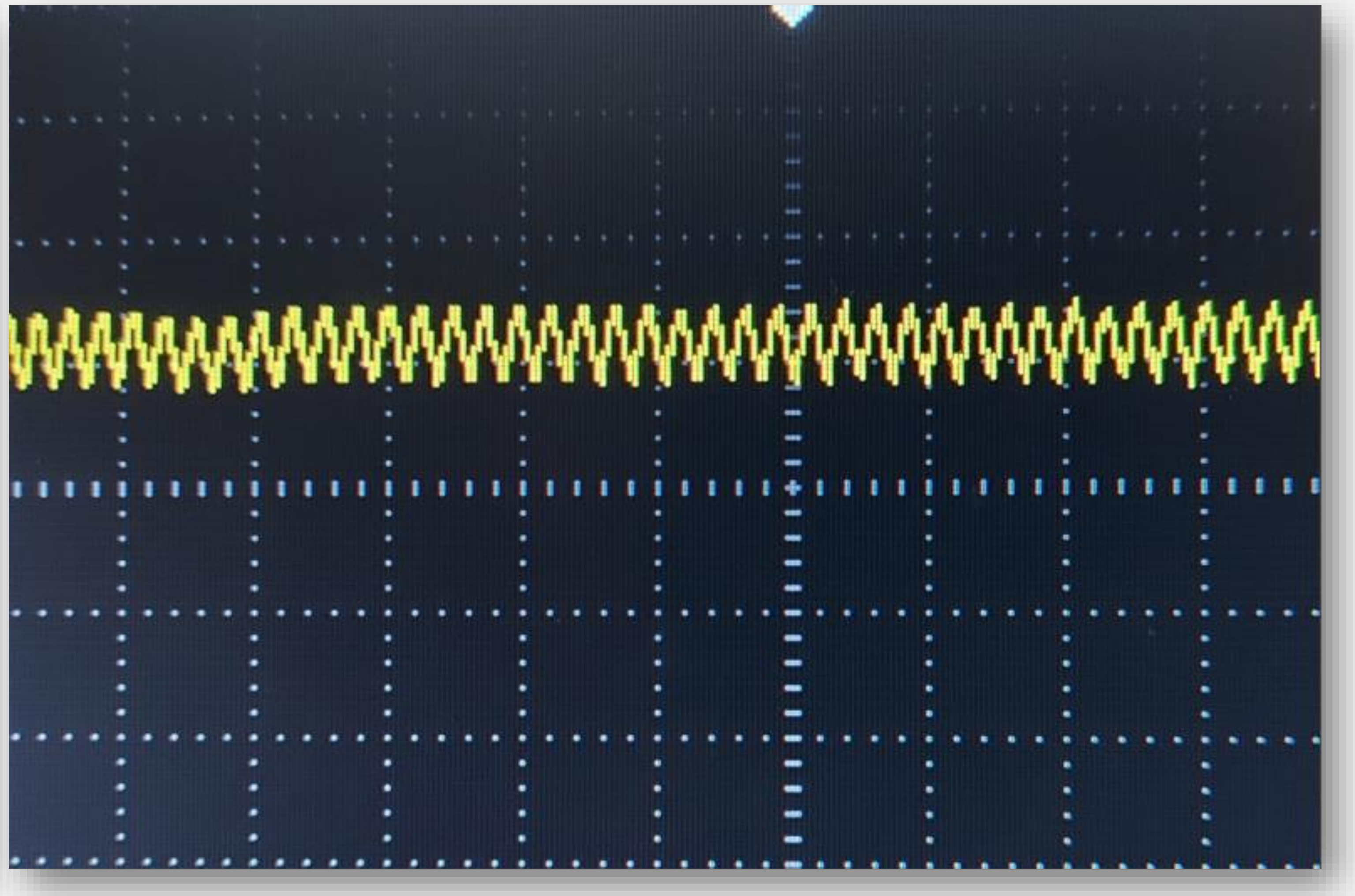
FILTER VALIDATION

- Arbitrary waveform generator
- Oscilloscope values vs simulated attenuation levels









DESIGN VALIDATION PLAN – ELECTRICAL

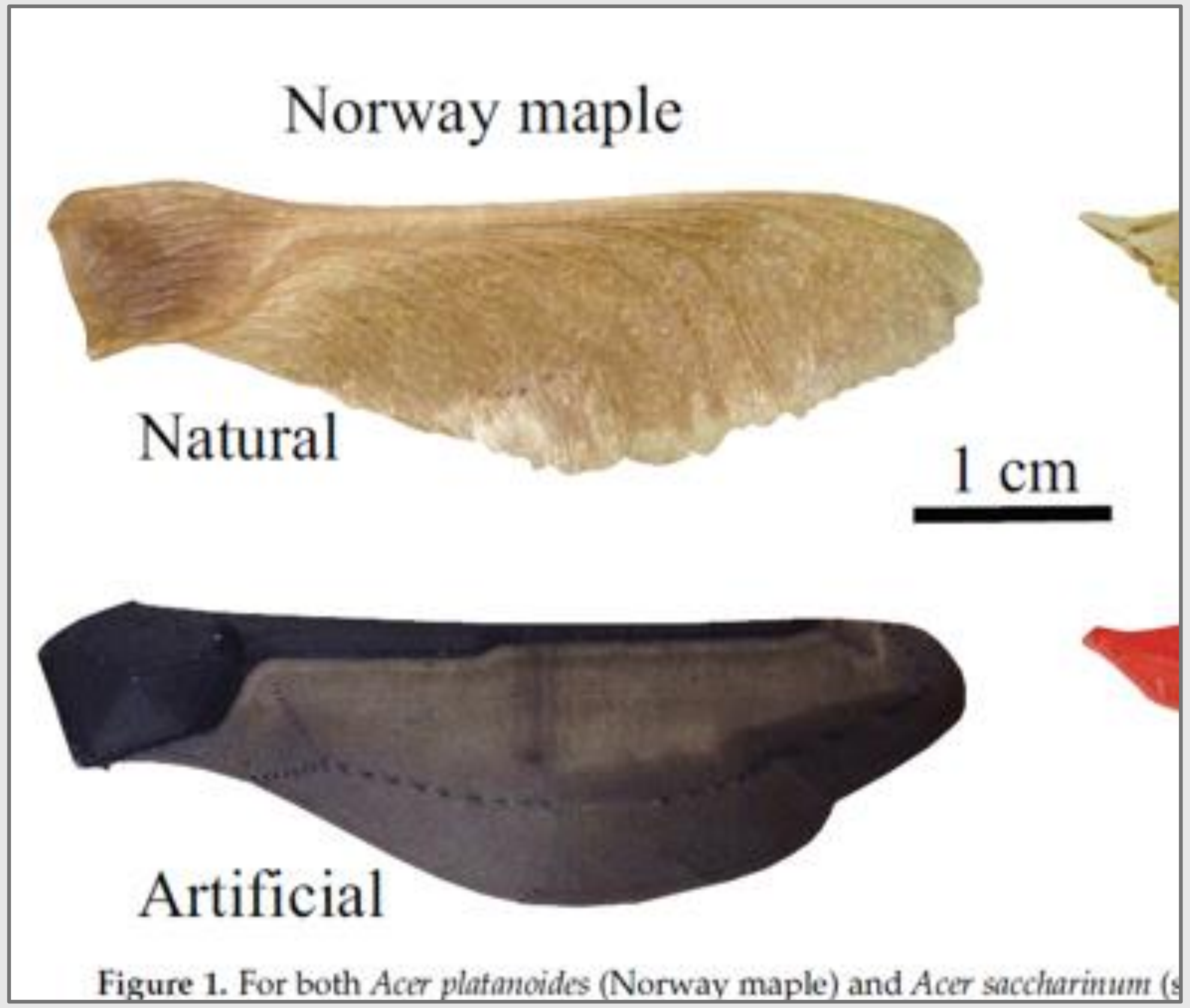
Requirement	Test	Test Subject	Target Date	Result	Recommendation
Constant voltage bus level at or below 3.3V	Circuit analysis with chosen battery component	Battery Array	2/18/22	Voltage bus varies from 3.75V-4.35V	Include a 3.3V regulator between the battery array and the rest of the system
Target per-unit cost reduction (>=20%)	Previous design per-unit cost averaged $50	Prototype (Electrical System)	4/15/22	Current design per-unit cost averages $32, resulting in a 36% cost reduction	Bare chip design would further reduce per-unit cost, but can't be done in-house
Target power source lifetime of 30 days (730 hours)	Calculate max power consumption of full system and extrapolate	Prototype (Electrical System)	3/18/22	Ongoing	The modular battery array can be expanded to provide more capacity
Detection of characteristic low frequency signature (sub-20 Hz)	Produce artificial input signal to test Chebyshev filtering	Chebyshev Filter	4/7/22	Schematic error: -3.3V required on 3rd op-amp V- terminal Attenuation of ~-40 mV signal from 20 Hz to ~-10 mV at 80 Hz	Update circuit schematic with corrections Reduce gain on inverting amplifier circuit

PAYLOAD DESIGN

PROBLEM STATEMENT
PROTECT THE ELECTRONICS SYSTEM

Last Year's Prototype:

Water-tight | Inexpensive | Robust



Samara (Maple) Seed:

Reduces Velocity | One Mechanical Body | Rapid Manufacturability

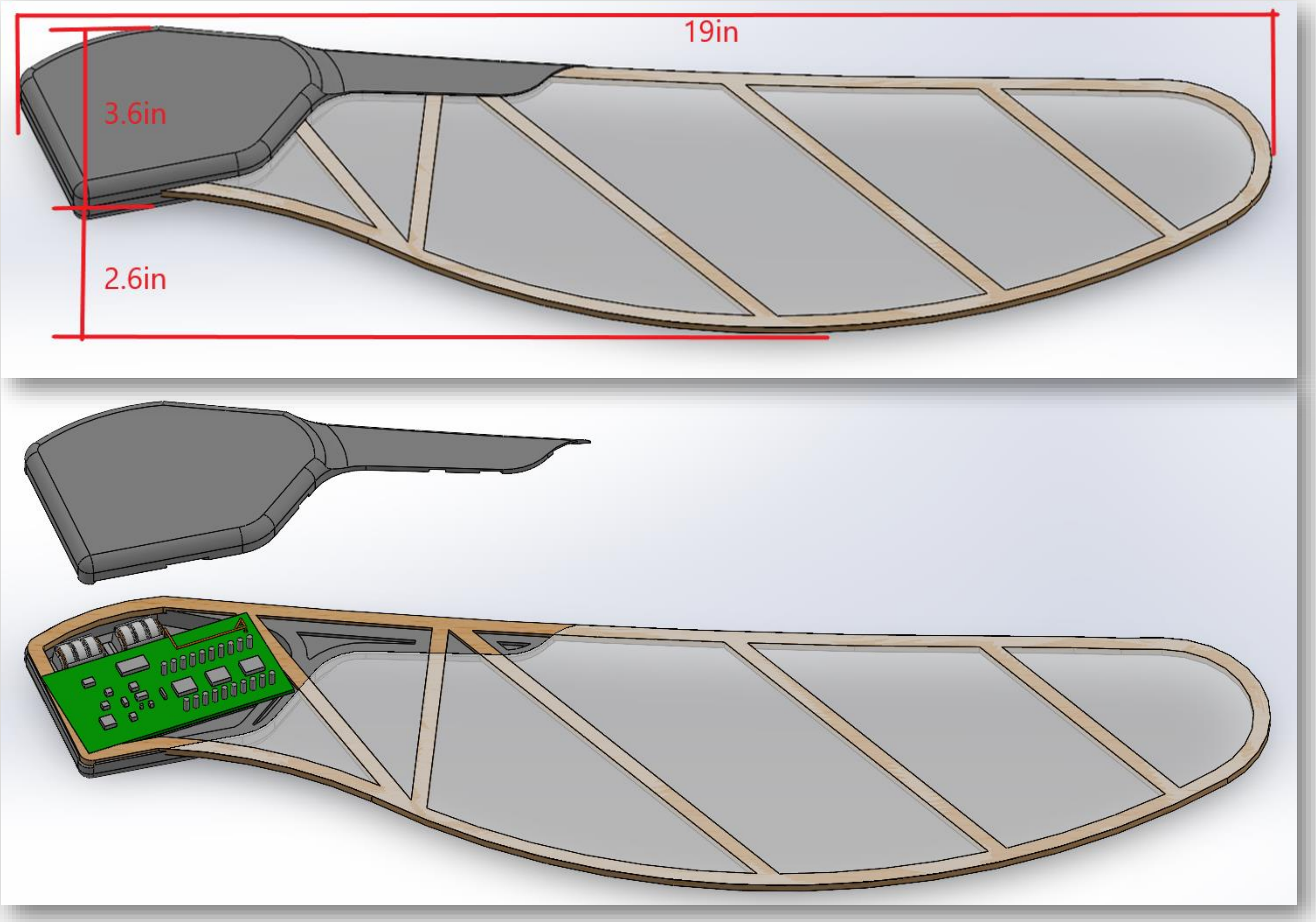
PAYLOAD DESIGN/STRUCTURE

Key Principles:

- Center of Mass
- Center of Pressure
- Wing Shape and Size

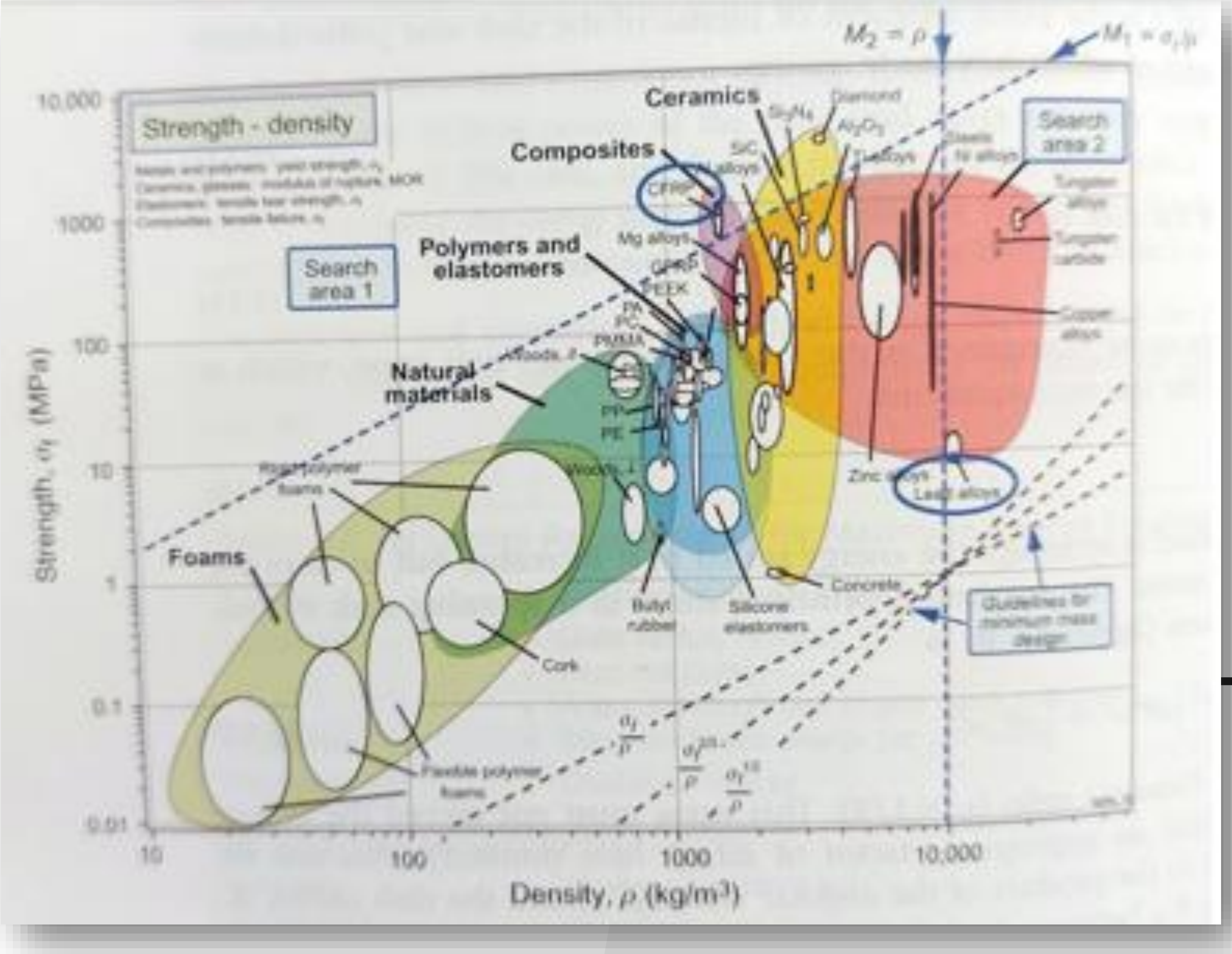
Placement

- PCB → Nut
- Batteries → Nut, Edge
- Wing → Skeleton, Skin



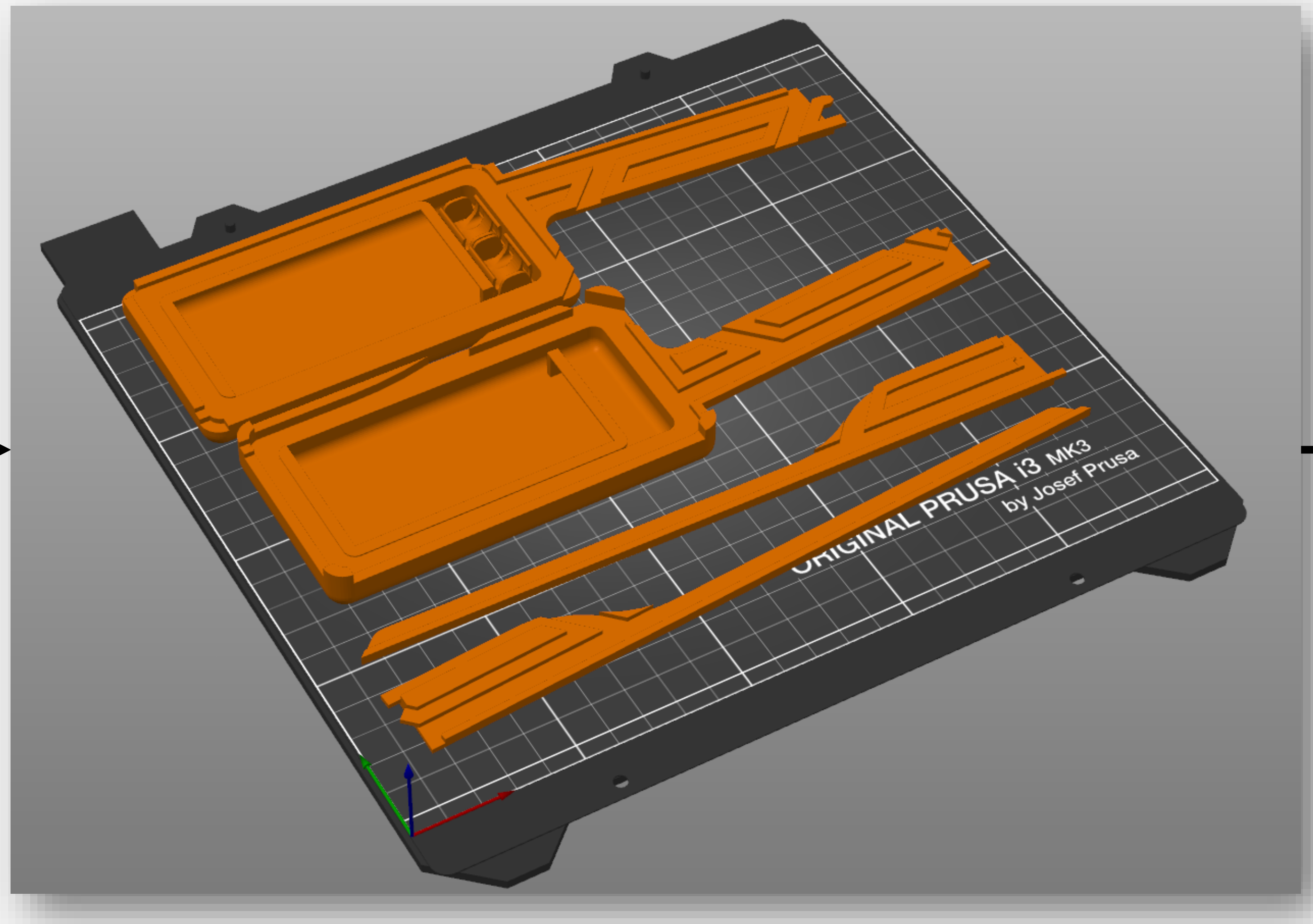
PAYLOAD DESIGN/STRUCTURE

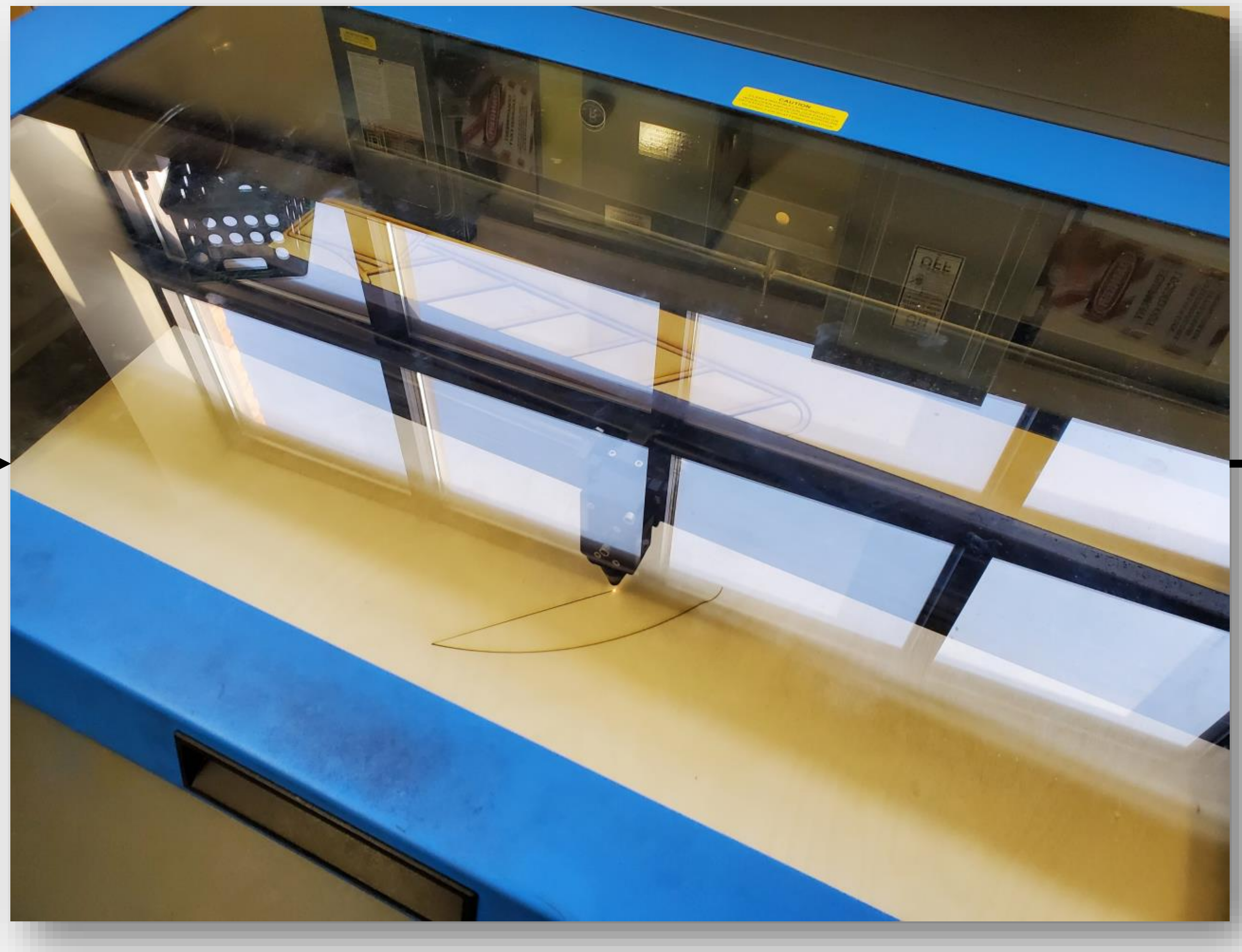
MATERIALS AND MANUFACTURING



$$M = \frac{\sigma^{\frac{2}{3}}}{\rho}$$

3D Printed PLA Plastic





Laser Cut Birch Wood

TESTING: EXPERIMENTAL MODELS

1/5 SIZE DROP TESTS – IDEAL WING SHAPE

<u>Wing Shape A</u>

Typical maple seed shape

<u>Wing Shape B</u>

Wider wing

<u>Wing Shape C</u>

Longer wing

- Drops from 18.5ft
- Conditions calm with gusts

TESTING: EXPERIMENTAL MODELS

1/2 SIZE DROP TESTS

Drop Testing Conditions:

18.5ft, clear wind, 6 tests

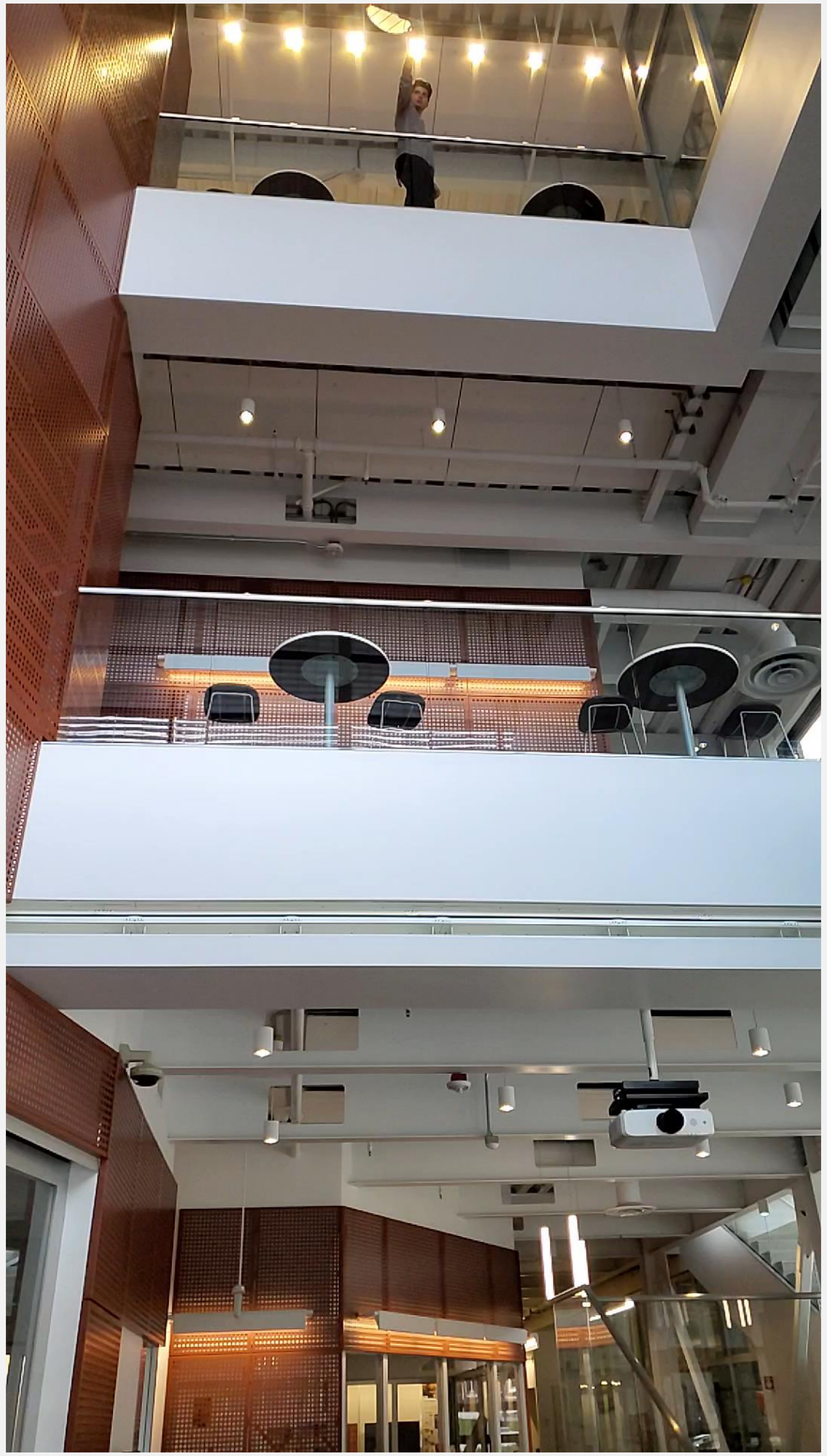
Average drop time: **2.44s**

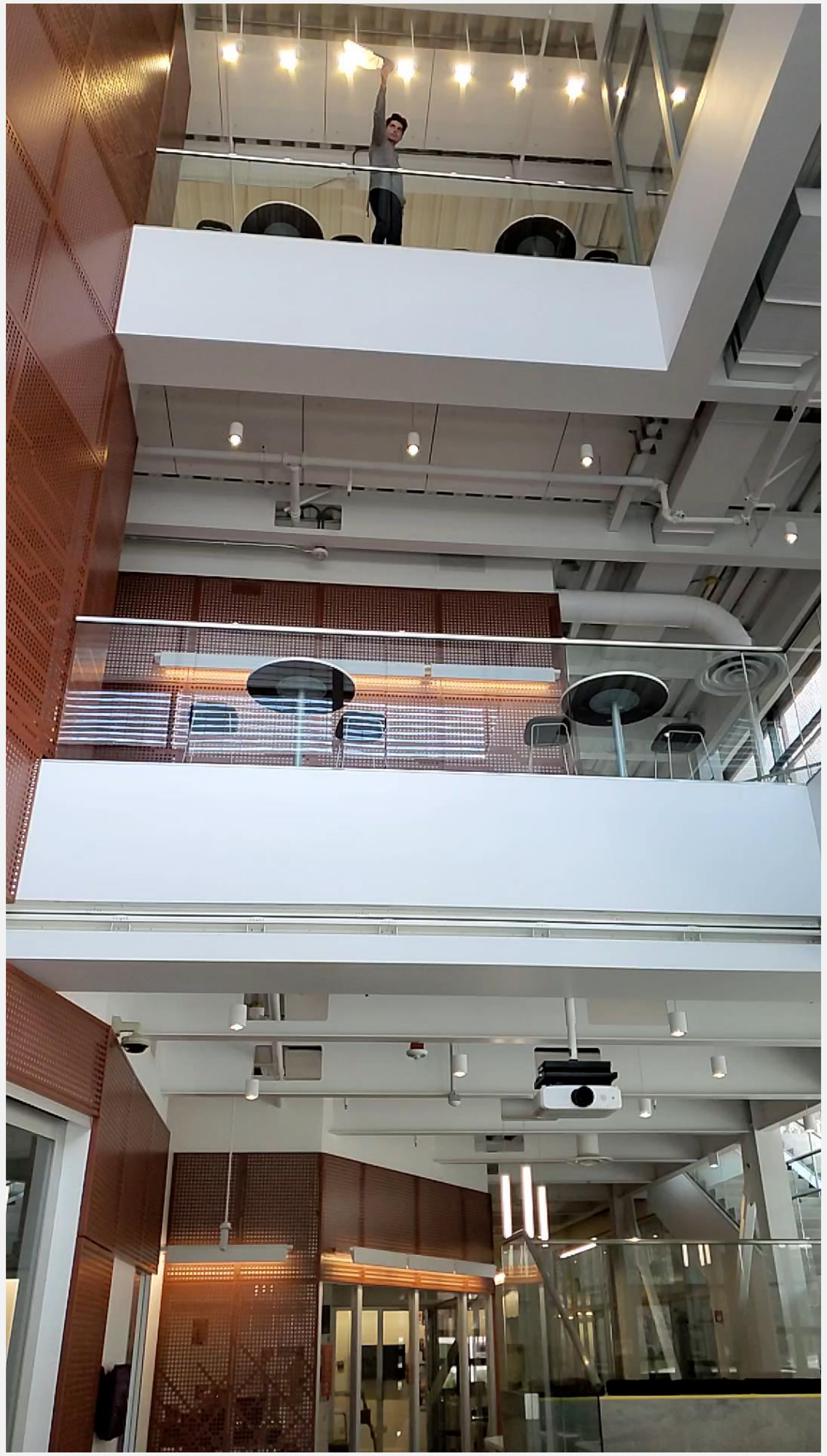
Impact Velocity: **7.6ft/s**

Why:

- Fall time and velocity
- Weight distribution
- Fall time scaling

TESTING: FULL ASSEMBLY

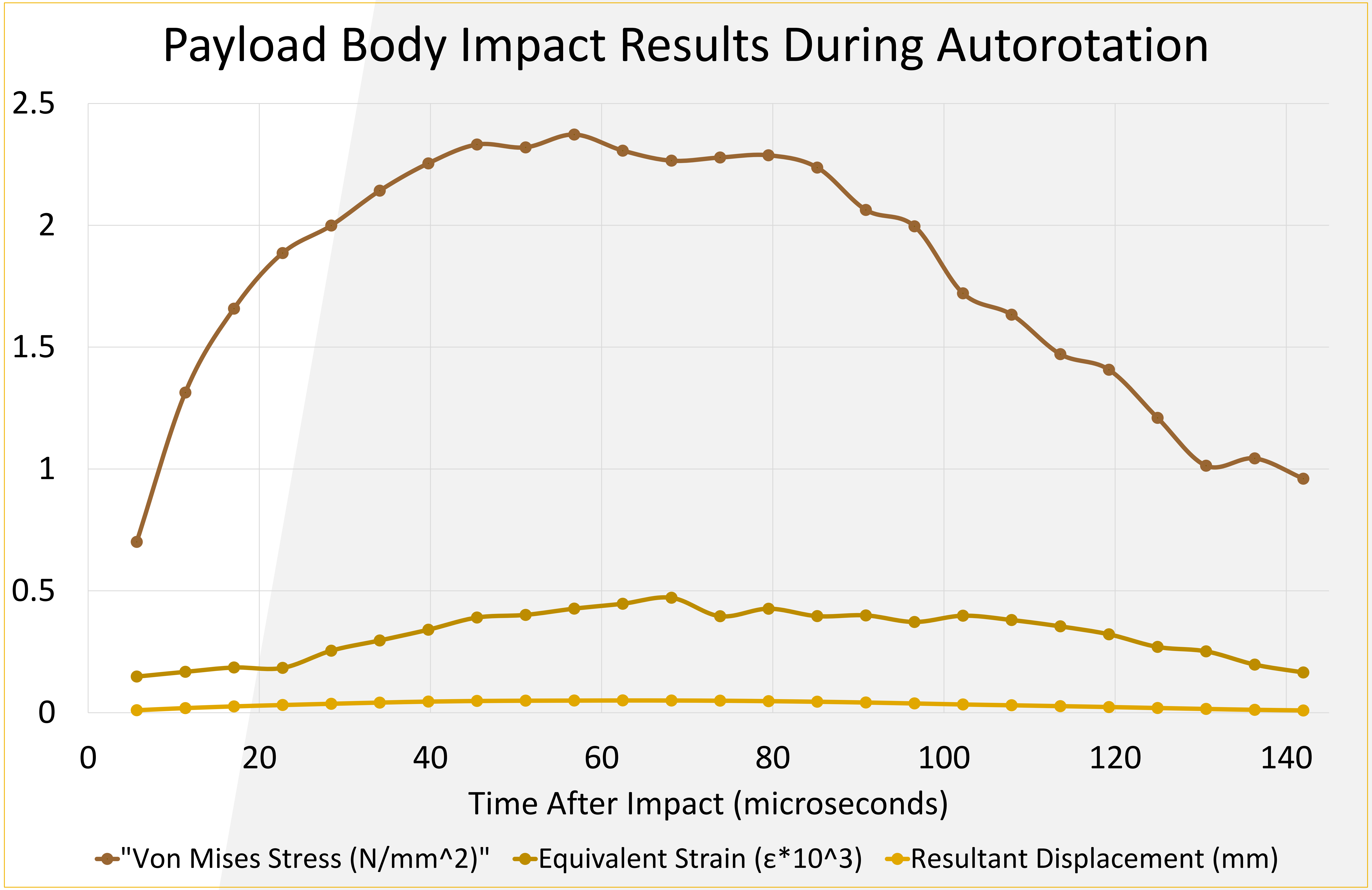


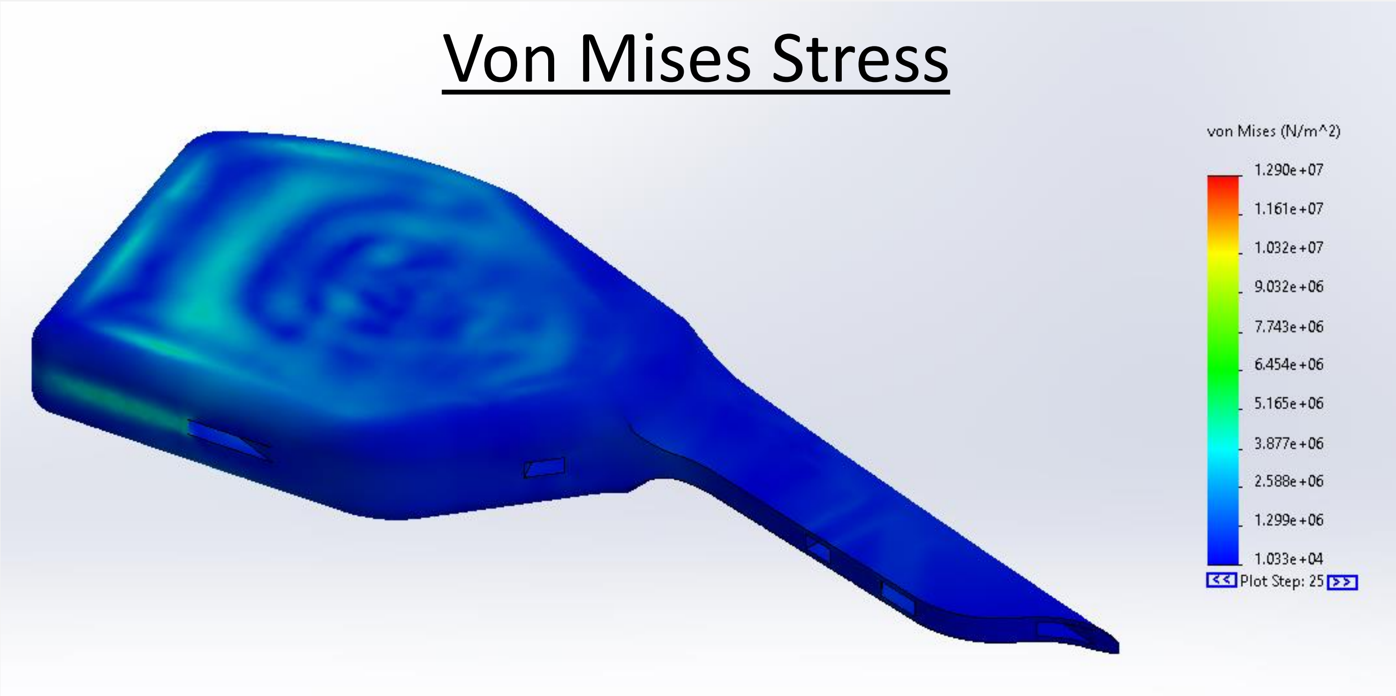


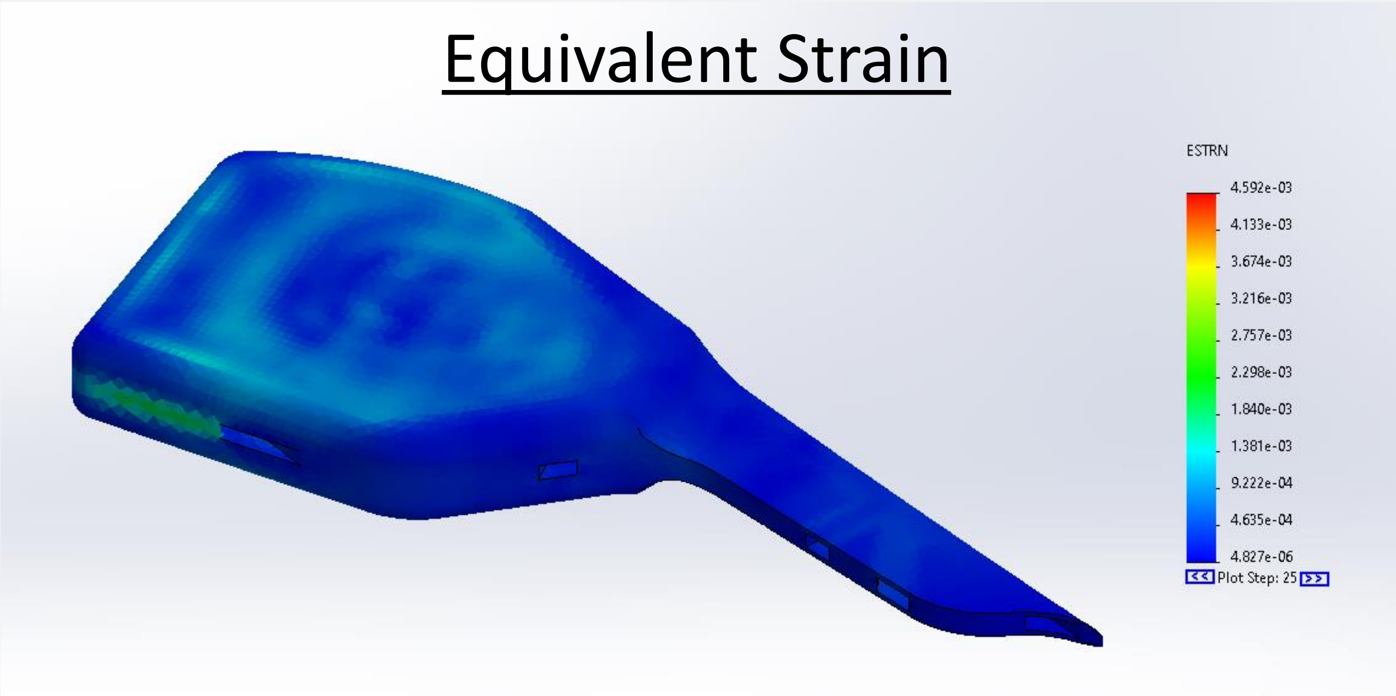
Drop Testing Results

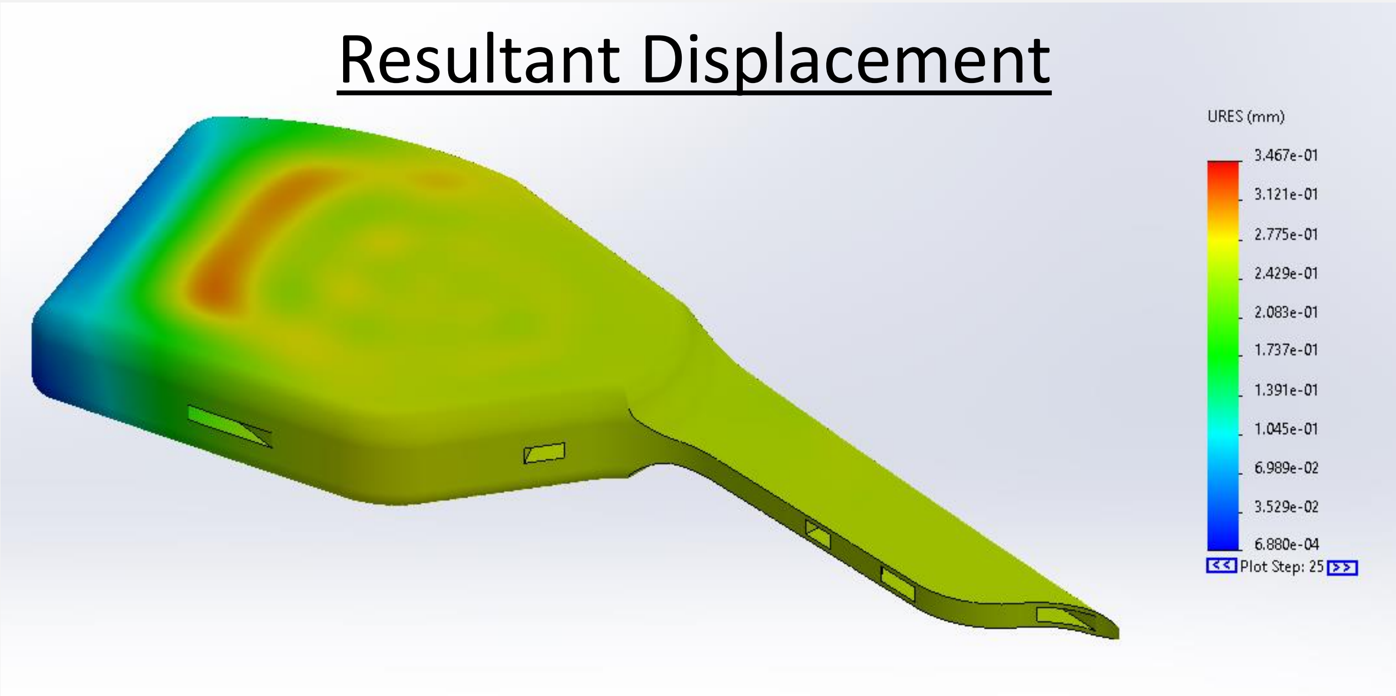
- Impact Velocity: **1.83m/s**
- Impact Angle: **29.3°**

IMPACT SIMULATION









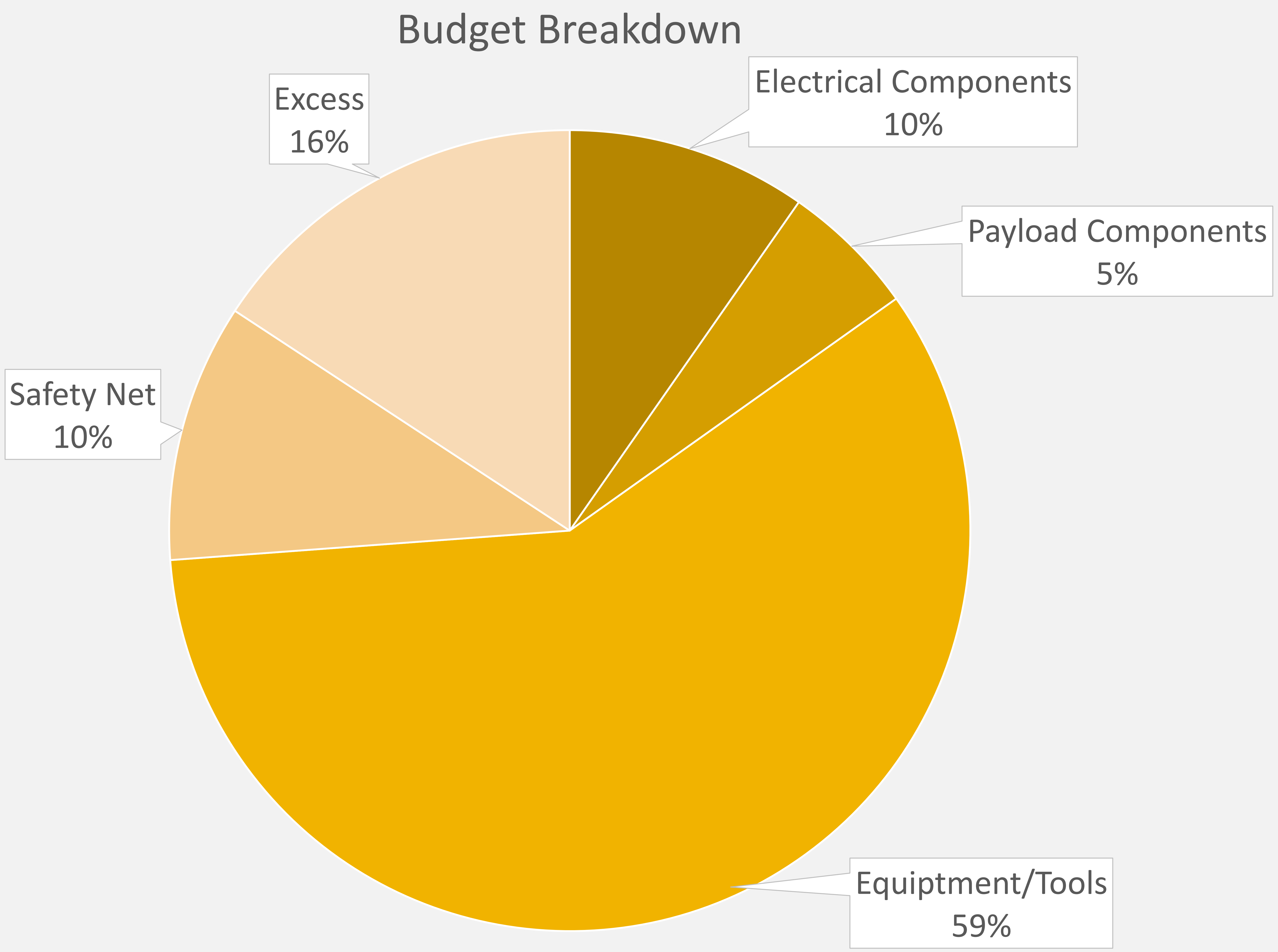
Tensile Yield Strength: 37.6MPa – 59.3MPa | Equivalent Strain: 0.016ε – 0.026ε

DESIGN VALIDATION PLAN – MECHANICAL

Requirement	Test	Test Subject	Target Date	Result	Recommendation
Investigate Samara Flight Characteristics	6ft Drop	Balsa Samara	12/23/2021	Multiple fractures in nut section.	Print plastic housing structure for sensor area and to distribute weight.
Reduce Velocity of Falling Payload	14ft Drop Tests	Samara's A, B, C, D	2/16/2022	Samara A and B selected for consideration	Test ½ models off shapes A and B
Protect Payload Electronics	14ft, 32ft Drop Tests	½ Scale Samara's	2/24/2022	Samara shape A was increased for drop testing outdoors and indoors.	Increase fracture resistance in nut. Expand wings larger than shape A.
Full System Integration Testing	32ft Drop Tests	Full Scale Samara	4/24/2022	No Rotation Achieved	Nut seems too heavy for nut-to-wing surface area ratio.
½ Scale with PCB Integration	32ft Drop Test	½ Scale Samara	4/27/2022	Orientation-dependent Rotation Achieved	Keep ½ Scale Model nut shape

PROJECT MANAGEMENT

TEAM BUDGET



Budget Breakdown
Electrical Components 10%
Payload Components 5%
Equiptment/Tools 59%
Safety Net 10%
Excess 16%

PROJECT SCHEDULE

OBJECTIVES FOR THIS YEAR

(January – February)

1. Design

2. Manufacturing

(February – March)

(March – April)

3. Testing & Validation

4. Product Release

(April 22nd)

(April 28th & 29th)

5. EXPO

6. Documentation

(April 22nd – May 13th)

THANKING OUR SPONSORS

Joe Stanley,
Stanley Solutions

Dr. Herbert Hess
U of I, ECE

Stanley Solutions

University of Idaho
College of Engineering

With special thanks to: Feng Li, Jack Gonzalez and Abdallah Smadi

University of Idaho

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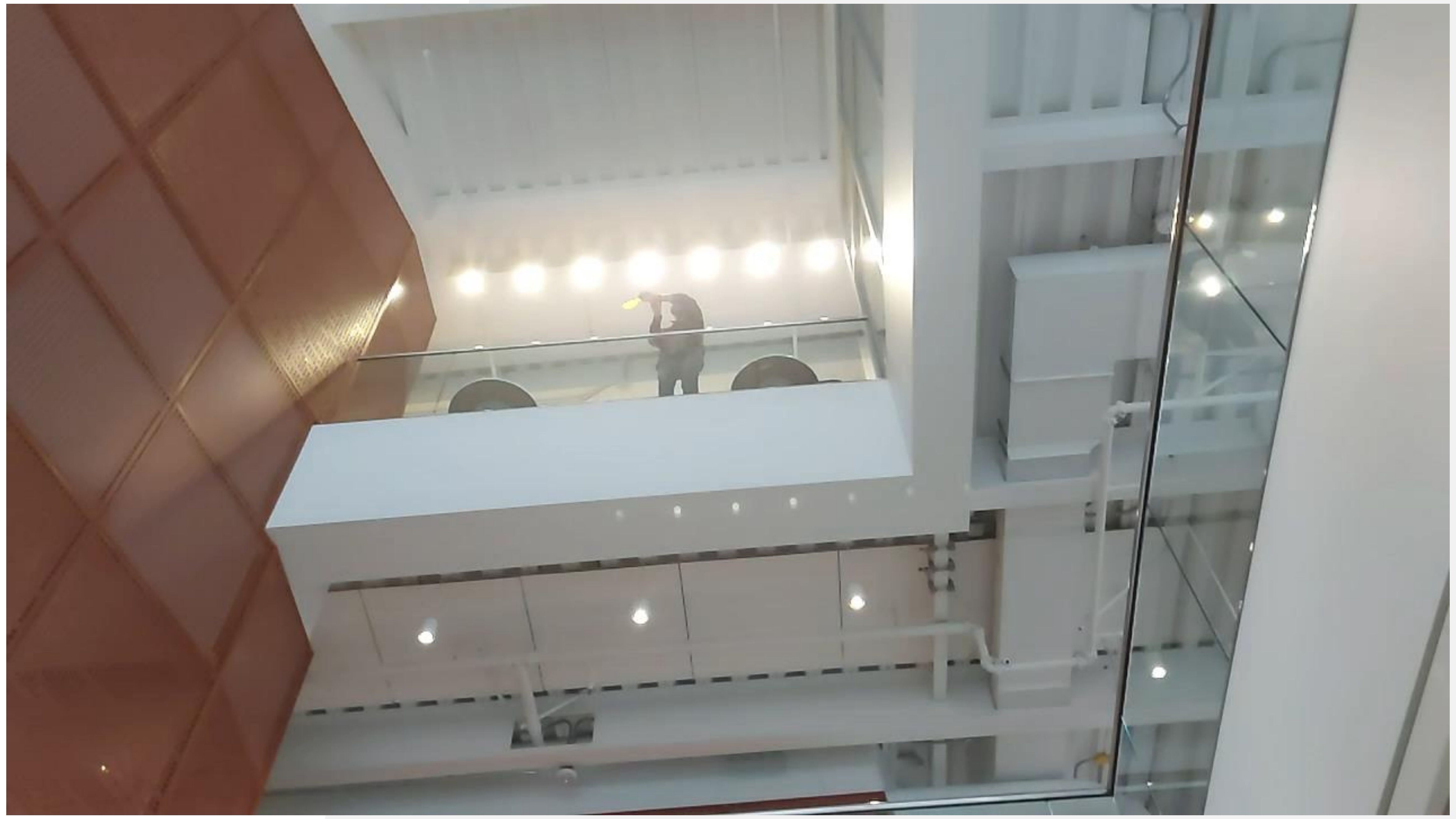
THANK YOU!

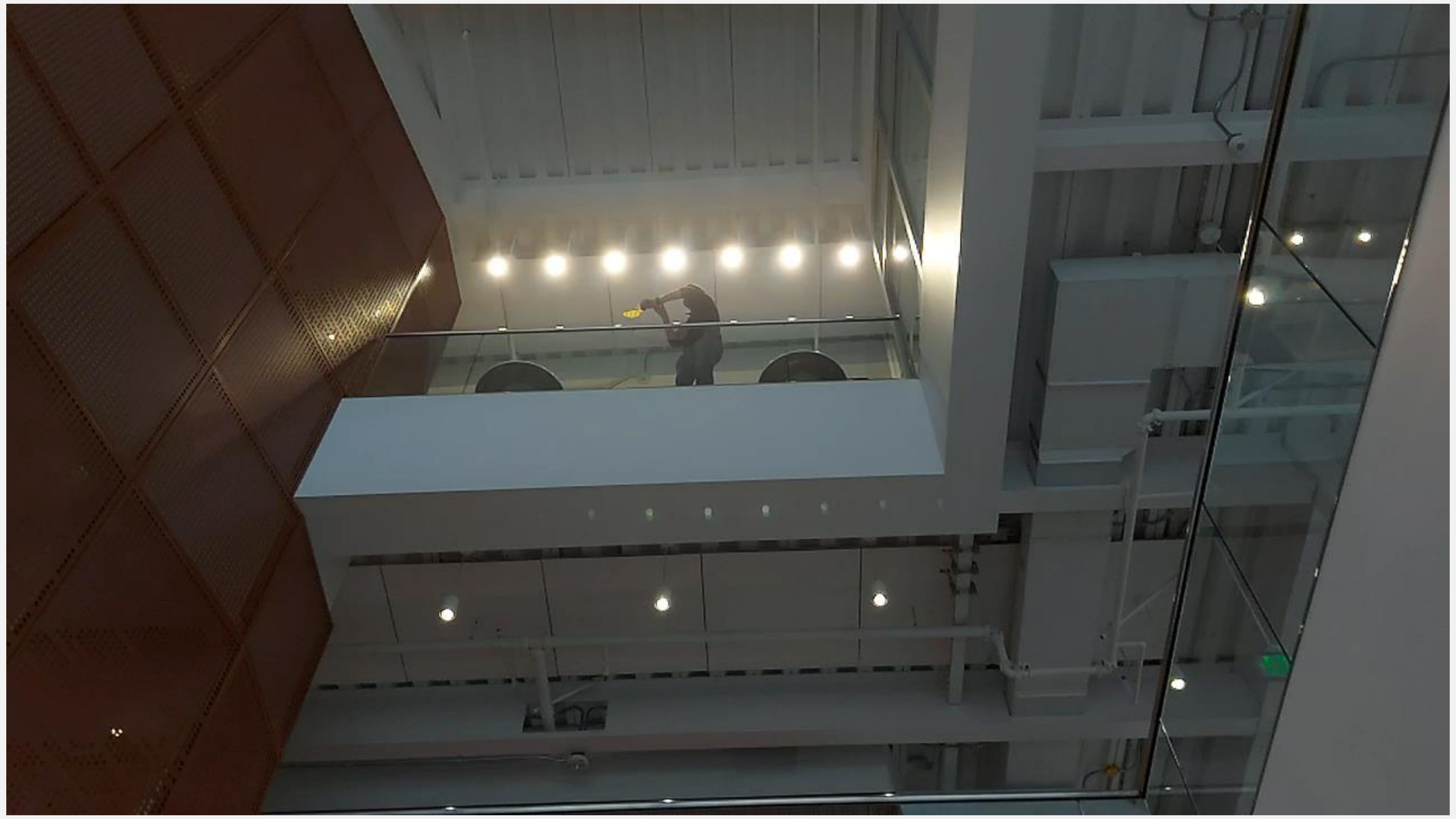
QUESTIONS?

ATRIUM ½ MODEL – DART MODE

Rotating Dart



Pure Dart



OUTSIDE ½ MODEL - DART TO ROTATION

OUTSIDE ½ MODEL – RANDOM TOSS